STABILITY ANALYSIS OF STRUCTURES

BIRCH HILL DAM

CONNECTICUT RIVER BASIN

MILLERS RIVER, MASSACHUSETTS

APRIL 1977

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASS.

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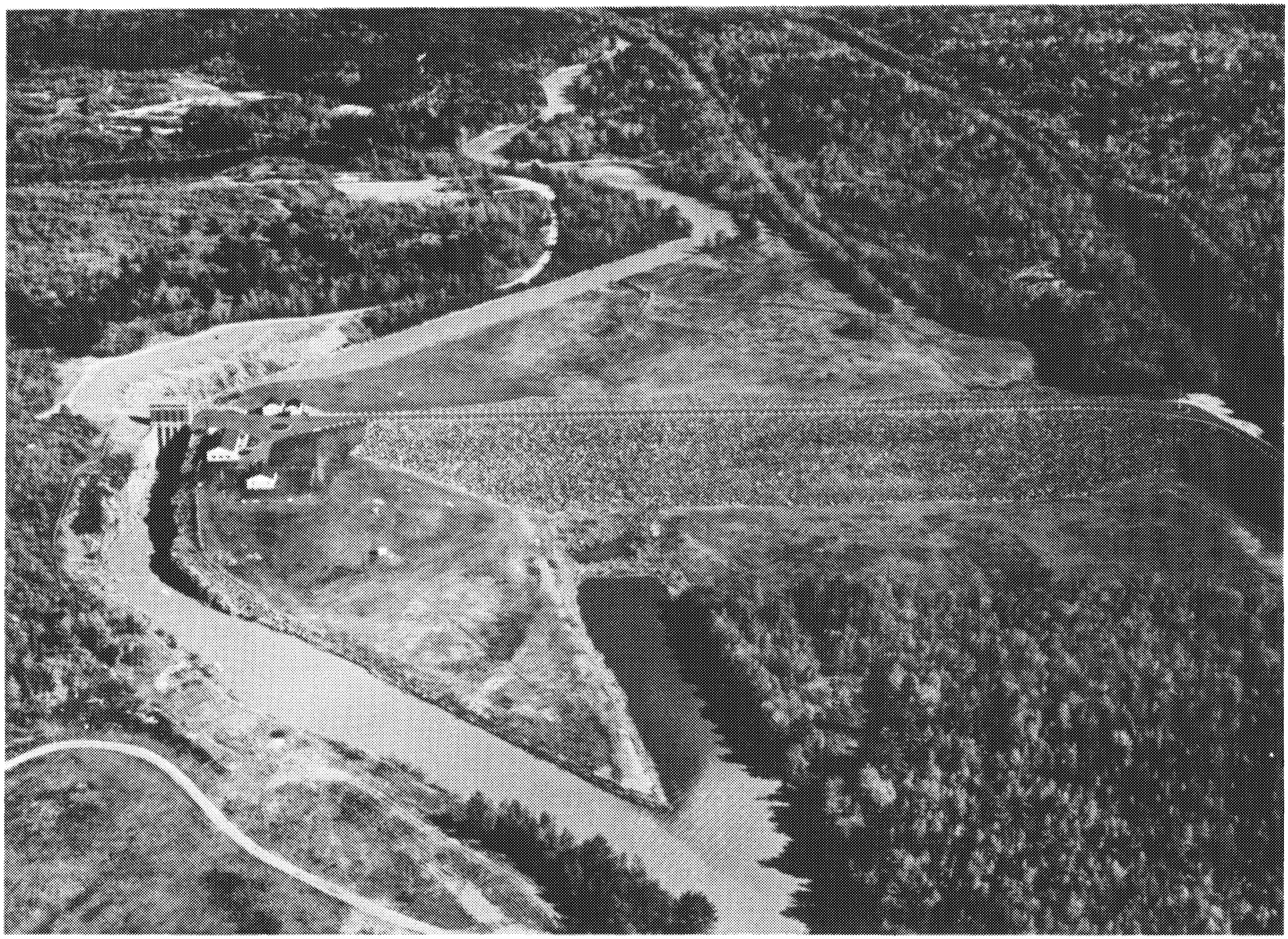

BIRCH HILL DAM MAY 1957

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(NOTE: APPENDIX B is a separate volume)

SUMMARY OF REPORT

A stability analysis of the principal concrete structures of Birch Hill Dam was performed to determine whether these structures satisfy current design criteria. The structural elements considered and the qualitative results of the analysis are as listed:

Structure	All Criteria Satisfied
Main Spillway	No
Auxiliary Spillway	No
Third Spillway	No
Gate Structure and Operating House	Yes
Inlet Channel Walls	Yes
Outlet Channel Walls	Yes

The analysis indicates that the three spillways do not satisfy current criteria for overturning. The load case which is critical for the spillways is a condition with the pool elevation at spillway crest combined with ice pressure. Installation of vertical rock anchors, at an estimated cost of $230,000, is recommended to strengthen the spillways.

STABILITY ANALYSIS OF STRUCTURES
BIRCH HILL DAM
PART I

GENERAL DESCRIPTION

1.1 Purpose

The objective of this study is to review the stability of the principal concrete structures, based upon current criteria in cases where the original design criteria were less conservative. This review has been performed to comply with Corps of Engineers regulation ER 1110-2-100, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures (26 Feb. 1973).

1.2 Stability Criteria

The current stability criteria by which this project was evaluated are contained in the following Corps of Engineers publications:

Engineering Manuals:

EM 1110-2-2101, Working Stresses for Structural Design (17 Jan. 1972)
EM 1110-2-2200, Gravity Dam Design (25 Sept. 1958)
EM 1110-2-2400, Structural Design of Spillways and Outlet Works (2 Nov. 1964)
EM 1110-2-2501, Wall Design: Flood Walls (18 June 1962)
EM 1110-2-2502, Retaining Walls (25 Jan. 1965)

Engineer Technical Letters:

ETL 1110-2-184, Gravity Dam Design (25 Feb. 1974)
ETL 1110-2-109, Structural Design for Earthquakes (21 Oct. 1970)

1.3 Pertinent References:

Pertinent data, computations, and drawings are contained in the following:

Project Data for Periodic Inspection - Birch Hill Dam (Aug. 1972)
Analysis of Design, Appendix A - Birch Hill Dam (1940)
Birch Hill Dam Contract Drawings (Jan. 1940)

1.4 Project Description

Birch Hill Dam is located on the Millers River, Massachusetts, a tributary of the Connecticut River, and is about 27.3 miles above its confluence with the Connecticut River. The project, completed in February 1942, is operated for flood control purposes.

The dam embankment is a rolled earth fill structure having a maximum height of 56 feet above the river bed and a total length of 1,400 feet. Its outlet works are in the right abutment and consist of an inlet channel, a gate structure, and an outlet channel. The gate structure with the gate house directly above forms the connecting link between the inlet and outlet channels. The main spillway, 810 feet long, is constructed on rock in a natural saddle on the right bank about 1,000 feet downstream from the centerline of the dam with a small auxiliary spillway, 350 feet long, located in a saddle adjacent to the main spillway. A third spillway, 30 feet long, is located at an abandoned railroad cut northwest of the dam. The spillways are uncontrolled concrete ogee weirs with a fixed crest at elevation 852 feet m.s.l., 12 feet below the crest of the dam.

At spillway crest, Birch Hill Reservoir extends upstream about 6.5 miles and has a capacity of 49,900 acre-feet. The total drainage area controlled by the dam is 175 square miles. Since the completion of the project, the major impoundments have been:

Year	Date	Maximum Water Surface Elevation (ft - msl)	Storage (acre-feet)	Use % of Total
1960	8 April	840.0	20,400	40
1969	24 April	837.5	16,000	32
1968	25 March	836.2	14,000	28
1948	25 March	835.2	12,500	26

1.5 Pertinent Hydraulic Data

The hydraulic data for structural stability are as follows:

	FULL POOL CONDITION (Reservoir at Spillway Crest)		DESIGN DISCHARGE CONDITION (Reservoir at SDF Maximum Surcharge Elevation)		
Spillway (ft)	Energy Gradient at Spillway (ft msl)	Tailwater Energy Gradient (ft msl)	Energy Gradient at Spillway (ft msl)	Tailwater Energy Gradient (ft msl)	Tailwater Water Surface (ft msl)
810	852.0	816.0 (Min)	857.8	853.6	853.4 (Min)
350	852.0	850.0	857.8	857.1	854.5 (Min)
30	852.0	846.0	857.8	856.6	855.8

In the original computations of 1940, the maximum surcharge elevation of the reservoir is given as 859 feet m.s.l.

1.6 Discussion of Analysis and Criteria

The principal structural elements which were analyzed for stability consist of the following:

a) Main Spillway (810 feet long)
b) Auxiliary Spillway (350 feet long)
c) Third Spillway (30 feet long)
d) Gate Structure and Operating House
e) Inlet Channel Walls
f) Outlet Channel Walls

The adequacy of sliding resistance of structures subjected to lateral loadings is determined by the use of the shear-friction factor of safety formula as outlined in ETL 1110-2-184 (25 Feb. 1974). Sliding stability is evaluated by comparing the available sliding resistance with the lateral force tending to induce sliding. For the gate structure and operating house and spillways, a minimum shear-friction factor of safety of 4.0 is required for all conditions of loading when earthquake is not considered. For loading conditions where earthquake is considered this factor of safety should exceed 2.67. Inlet and outlet channel walls should have a factor of safety greater than 1.5 for all loading conditions. Sliding stability was not checked in the original computations of 1940.

The resistance to overturning is determined according to current criteria by the location of the resultant of vertical forces at the base. The resultant should be located within the middle third of the base for all conditions of loading when earthquake is not considered. For loading conditions where earthquake is considered, it is acceptable if the resultant stays within the base, provided that allowable foundation pressures are not exceeded. For retaining walls founded on rock, the resultant may be outside the middle third, but within the base, if foundation pressures are within allowable values and the factor of safety against sliding is adequate.

Earthquake forces were not considered in the original computations. Birch Hill Dam is located in Seismic Zone 2 (moderate damage), as shown on the Seismic Risk Map of the United States, included with ETL 1110-2-2200 (21 Oct. 1970). Therefore, this analysis takes into account earthquake forces induced by accelerations equal to 0.10g.

In accordance with EM 1110-2-2200 (25 Sept. 1958), the seismic forces applied to this stability analysis are as follows:

a) Inertia force Pe_1 due to acceleration of the structure, acting through the center of gravity in any direction. $Pe_1 = 0.10W$, where, W is the weight of the structure.

b) Inertia force Pe_2 induced by the impoundment of water. This force was computed using Westergaard's formula, as outlined in EM 1110-2-2200 (25 Sept. 1958). The following parameters were used throughout: acceleration equal to 0.10g, period of vibration equal to 1 second.

c) Dynamic earth pressure, in accordance with EM 1110-2-2502 (25 Feb. 1974), was applied at a distance of 2/3 the fill height from the base. The pressure is assumed equal to 20 percent of static lateral earth pressure. The backfill between a sloping wall and a vertical plane through the heel was added to the wall mass for computation of inertia force Pe_1.

No vertical acceleration is considered in this analysis. Uplift is assumed unaffected by earthquake.

The uplift pressure at any point under a structure is the tailwater pressure plus the pressure measured as an ordinate from tailwater to the hydraulic gradient between the upstream and downstream pool. Uplift pressure is considered to act over 100 percent of the base area. Uplift pressure considered in the original computations was less than the value used in this analysis.

Ice pressure of 10,000 pounds per lineal foot of structure was applied to this analysis in accordance with EM 1110-2-2200 (25 Sept. 1958). Ice pressure was not considered in the original computations.

Wind pressure of 30 pounds per square foot is used in this stability investigation.

1.7 Discussion of Foundation and Foundation Parameters

All of the structural elements considered in this stability analysis are founded on rock. The three spillways are embedded a minimum of 3 feet into rock. Embedment of the gate structure and operating house into rock is approximately 40 feet on the north side (right abutment) and approximately 25 feet on the south side (left abutment). The inlet channel walls and the outlet channel walls are founded on rock and concrete lined rock. As described in Project Data for Periodic Inspection - Birch Hill Dam (Aug. 1972), the bedrock is composed of two types: medium to coarse foliated gray granite, and biotite mica schist. None of the structural elements considered is mechanically anchored to the rock foundation.

Allowable bearing pressure on the bedrock described above was not given in the original computations. For this analysis, bearing pressures less than 6 tons per square foot are assumed to be non-critical.

Allowable shearing stress for the two types of bedrock described would be higher than the allowable stress for the bonded surface between rock and concrete. Therefore, throughout this analysis, the critical sliding plane of resistance is assumed to be the plane of contact between the concrete and the rock foundation.

All three spillways have earth backfill on the upstream side. Lateral pressures induced by this fill are considered to be active earth pressures. Earth backfill on the downstream side of the spillway may be eroded when spillway discharge occurs and, thus, is assumed to be non-effective in resisting overturning and sliding.

The inlet channel walls and the outlet channel walls retain earth backfill which extends approximately to the top of the walls. At-rest earth pressure is used for analysis of walls in accordance with EM 1110-2-2502 (25 Jan. 1965).

Foundation parameters used for this analysis are as follows:

a) Allowable bearing on rock - 6 tons per square foot (conservative assumption due to lack of quantitative information on rock properties; assumed value is much less than the allowable bearing stress of concrete).

b) Shear at interface between rock and concrete - 80 pounds per square inch (based on ACI 318-71, composite concrete, allowable bond shear stress for clean and intentionally roughened contact surfaces without mechanical anchorages).

c) Coefficient of frictional resistance = 0.5 (based on tangent of angle of sliding friction for concrete on rock).

d) Coefficient of active earth pressure = 0.35 (same as value used in original computations).

e) Coefficient of at-rest earth pressure = 0.5 (in accordance with EM 1110-2-2502 (29 May 1961).

1.8 Method of Computation

Stability analysis for all structural elements except the gate structure and operating house was performed using the computer program "DAMPAC", developed by the Corps of Engineers, New England Division.

"DAMPAC", Corps of Engineers Program No. 713 F5 DO 100 and 105, is a fully documented design package for stability analysis of concrete gravity dams.

Stability of the gate structure and operating house was investigated by manual calculations.

PART II

RESULTS OF THE ANALYSIS

2.1 Spillway Sections

The three ogee weir spillways were analyzed for stability. Three sections of the main spillway were investigated: maximum section (39 ft. height, 32.5 ft. base); intermediate section (27 ft. height, 26 ft. base); minimum section (13 ft. height, 17.58 ft. base). The typcial section (11 ft. height, 15.92 ft. base) of the auxiliary spillway and the typical section (9 ft. height, 14.08 ft. base) of the third spillway were also analyzed.

As outlined in EM 1110-2-2200 (25 Sept. 1958), the loading conditions which were considered for analysis of spillways are as follows:

Case I. Construction Condition. Spillway completed but no water in reservoir, no tailwater, wind load on downstream face.

Case II. Normal Operating Condition. Pool elevation at spillway crest. Minimum tailwater. Ice pressure.

Case III. Induced Surcharge Condition. Pool elevation at top of partially opened spillway gate. (This case is not applicable to this analysis because all spillways at Birch Hill are ungated).

Case IV. Flood Discharge Condition. Reservoir at maximum flood pool elevation. Tailwater at flood elevation. Tailwater pressure at 60 percent of full value, except that full value is used for computation of the uplift. No ice pressure.

Case V. Construction Condition with Earthquake. Earthquake acceleration in a downstream direction (thus directing inertia forces upstream). No water in reservoir. No wind load. No tailwater.

Case VI. Normal Operating Condition with Earthquake. Earthquake acceleration in an upstream direction (thus directing inertia forces downstream). Reservoir at spillway crest. Minimum tailwater. No ice pressure.

For Load Cases I through IV, stability criteria are satisfied if the resultant falls within the middle third of the base and the factor of safety against sliding is greater than 4.0. For Load Cases V and VI, stability criteria are satisfied if the resultant stays within the base, provided that allowable foundation pressures are not exceeded, and the factor of safety against sliding is greater than 2.67.

Tables 1 through 3 contain the results of the spillway stability analysis. It should be noted that none of the spillway sections investigated satisfy the overturning criteria for Load Case II. Of particular importance is the fact that for the auxiliary spillway and the third spillway the resultant falls outside the base. The main spillway also does not satisfy overturning criteria for Load Case IV. For all sections considered, the factor of safety against sliding is acceptable and foundation pressures are within allowable values.

The two conclusions which are drawn from this analysis may be summarized as follows:

a) If the water level of the impoundment reaches spillway crest and freezes, thus introducing the possibility of an increased lateral pressure due to the expansion of ice, there is a definite danger of structural failure of the spillways due to overturning instability.

b) Concerning the main spillway, the location of the resultant outside the middle third of the base for Load Case IV does not appear to be critical, but this does indicate that the factor of safety against overturning which is required by current criteria is not provided.

2.2 Gate Structure and Operating House

The gate structure and operating house is located on the center line of the dam at the right abutment. The total height of the structure from the roof top of the operating house to the bottom of the gate structure base slab is 83 feet. Stability was investigated about two axes: the weak axis (perpendicular to the flow), and the strong axis (parallel to the flow).

As outlined in EM 1110-2-2400 (2 Nov. 1964), the loading conditions which were considered for analysis of the gate structure and operating house are as follows:

Case I. Reservoir empty. Wind load to produce most severe foundation pressures.

Case II. Gate structure with all gates open. Reservoir at spillway crest. Ice pressure. Uplift. Water surface inside structure drawn down to hydraulic gradient with all gates open.

Case III. Similar to Case II, except that gate structure operating with one outside gate closed, others open. (For this analysis, service gate assumed to be closed).

Case IV. Gate structure with gates closed. No flow in conduits. Reservoir at spillway crest. Ice pressure. Uplift. Structure full of water upstream from closed gates. (For this analysis, service gates assumed to be closed).

TABLE 1

STABILITY ANALYSIS OF MAIN SPILLWAY

Section (1)	Loading Case	Location of Resultant In Middle Third	Location of Resultant In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure on Rock Kips/S.F. Upstream	Bearing Pressure on Rock Kips/S.F. Downstream
Max. Sect.	I	yes	-	1222.2	32.50	6.95	0.14
Ht. = 39 ft.	II	no	yes	6.5	22.39	0	6.46
Base = 32.5 ft.	III	Case III	not applicable				
	IV	no	yes	8.6	27.07	0	2.20
	V	no	yes	35.7	29.04	7.91	0
	VI	no	yes	5.9	27.93	0	5.18
Intermed. Sect.	I	yes	-	6684.8	26.00	4.72	0.65
Ht. = 27 ft.	II	no	yes	9.7	16.94	0	5.61
Base = 26 ft.	III	Case III	not applicable				
	IV	no	yes	13.2	23.96	0	3.01
	V	yes	-	54.9	26.00	5.27	0.06
	VI	yes	-	9.9	26.00	0.23	3.42
Min. Sect.	I	yes	-	454.7	17.58	2.21	0.56
Ht. = 13 ft.	II	no	yes	13.3	2.92	0	11.73
Base = 17.58 ft.	III	Case III	not applicable				
	IV	no	yes	25.3	17.34	0	1.30
	V	yes	-	136.1	17.58	2.41	0.36
	VI	yes	-	23.9	17.58	0.61	1.34

(1) See Plates 3 and 4 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, cofficient of friction of 0.5, and neglecting passive resistance of rock.

TABLE 2

STABILITY ANALYSIS OF AUXILIARY SPILLWAY

Section (1)	Loading Case	Location of Resultant: In Middle Third	Location of Resultant: In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure on Rock Kips/S.F.: Upstream	Bearing Pressure on Rock Kips/S.F.: Downstream
Typ. Sect.	I	yes	-	177.3	15.92	1.79	0.61
Ht. = 11 ft.	II	no	no	15.6	0	-	-
Base = 15.92 ft.	III	Case III	not applicable				
	IV	yes	-	28.7	15.92	0	1.13
	V	yes	-	394.5	15.92	1.95	0.45
	VI	yes	-	42.8	15.92	0.62	0.73

(1) See Plates 3 and 4 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, coefficient of friction of 0.5, and neglecting passive resistance of rock.

TABLE 3

STABILITY ANALYSIS OF THIRD SPILLWAY

Section (1)	Loading Case	Location of Resultant: In Middle Third	Location of Resultant: In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure on Rock Kips/S.F.: Upstream	Bearing Pressure on Rock Kips/S.F.: Downstream
Typ. Sect.	I	yes	-	994.7	14.08	1.51	0.52
Ht. = 9 ft.	II	no	no	13.3	0	-	-
Base = 14.08 ft.	III	Case III	not applicable				
	IV	yes	-	39.3	14.08	0.15	0.87
	V	yes	-	170.8	14.08	1.61	0.40
	VI	yes	-	39.5	14.08	0.51	0.77

(1) See Plates 3 and 4 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, coefficient of friction of 0.5, and neglecting passive resistance of rock.

Case V. Reservoir raised to spillway design flood level for whichever of preceding Cases II, III, or IV is most critical. No ice pressure. (For this analysis, Case II is critical for stability about weak axis and Case III is critical for stability about strong axis).

Case VI. Bulkheads in place. Reservoir at maximum level at which bulkheads are used. (Since the gate structure does not have bulkheads, this case is not applicalbe).

Case IA, IIA, IIIA, or IVA. Same as Case I, II, III, or IV respectively with earthquake load added, except that earthquake is substituted for wind in Case IA, and for ice in the other cases. (The water in the gate structure was added to the mass of the structure for computation of inertia forces).

For Load Cases II, III, IV, and VI, stability criteria are satisfied if the resultant falls within the middle third of the base and the factor of safety against sliding is greater than 4.0. For Load Cases I and V, stability criteria are satisfied if 75 percent of the base is in compression and the factor of safety against sliding is greater than 4.0. For Load Cases IA, IIA, IIIA, and IVA, stability criteria are satisfied if the resultant stays within the base, provided that allowable foundation pressures are not exceeded, and the factor of safety against sliding is greater than 2.67.

Stability about the strong axis (parallel to the flow) is not critical for any of the specified loading cases. Table 4 contains the results of the stability analysis about the weak axis (perpendicular to flow). A review of these results indicates that the resultant falls outside the middle third of the base for Cases II and IV. Sliding criteria and foundation pressures are satisfied for all loading cases.

This analysis does not take into account the extra stability provided by the embedment of the gate structure into rock on both the north and south sides. For this reason, the location of the resultant outside the middle third of the base for Cases II and IV is not considered to be critical, and it is concluded that the gate structure and operating house is stable for all of the specified loading cases.

2.3 Inlet Channel Walls

River flow is channelized between concrete lined rock slopes starting upstream at Station 13+85 and ending at the gate structure, Station 14+87.12. The inlet channel walls form the top part of the concrete lining and retain earth fill. Cross sections of the walls vary over the entire length. Two sections of the south wall and one section of the north wall were checked for stability. The sections and the respective elevations at which stability was investigated are as follows: Sta. 14+52, south wall, El. 838.0; Sta. 14+87.12, south wall El. 838.0; Sta. 14+87.12, north wall El. 854.0.

TABLE 4

STABILITY ANALYSIS OF GATE STRUCTURE AND OPERATING HOUSE

Section (1)	Loading Case	Location of Resultant: In Middle Third	Location of Resultant: In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure on Rock Kips/S.F.: Upstream	Bearing Pressure on Rock Kips/S.F.: Downstream
Sect. parallel	I	yes	-	241.5	45.92	3.63	2.67
to flow	II	no	yes	11.2	42.57	0	5.10
Ht. = 83 ft.	III	Case III	not checked - approximately similar to Case II				
Base = 45.92 ft.	IV	no	yes	10.0	43.38	0	5.59
	V	yes	-	15.6	45.92	0.22	3.96
	VI	Case VI	not applicable				
	IA	yes	-	41.6	45.92	4.42	1.88
	IIA	no	yes	8.8	38.46	0	5.64
	IIIA	Case IIIA	not checked - approximately similar to Case IIA				
	IVA	no	yes	8.2	39.87	0	6.08

(1) See Plates 6, 7 and 11 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, coefficient of friction of 0.5.

As outlined in EM 1110-2-2400 (2 Nov. 1964) in the section entitled, "Approach Channel Walls", the loading conditions which were considered for analysis of the inlet channel walls are as follows:

Case I. Channel empty. Backfill naturally drained.

Case II. Partial sudden drawdown of reservoir from design flood level. Water in channel to drawdown elevation which may occur suddenly. Fill submerged to profile reached during design flood, drained above. (For this analysis, consider drawdown from El. 857.8 to El. 852.0).

Case III. Sudden rise of reservoir to design flood elevation. Water in channel to design flood elevation. Fill submerged to concurrent water surface in fill, naturally drained above. Water above fill to design flood elevation.

Case IA. Same as Case I with earthquake load added.

For all load cases considered, stability criteria are satisfied if the resultant stays within the base, provided that allowable foundation pressures are not exceeded, and the factor of safety against sliding is greater than 1.5.

Table 5 contains the results of the stability analysis of the inlet channel walls. This tabulation indicates that all the sections analyzed meet the criteria for overturning, sliding, and foundation pressures. It should be noted, however, that the resultant falls outside the middle third of the base for all sections when analyzed for load condition II, and although this is not a critical point, it does indicate that should the reservoir reach the maximum surcharge elevation, a rapid drawdown of the reservoir should be avoided when possible.

2.4 Outlet Channel Walls

Flow through the gate structure discharges directly into the outlet channel. The rock slopes on both the north and south sides of the outlet channel are lined with concrete starting at the gate structure, Station 15+12.87, and extending downstream to Station 15+73. The outlet channel walls form the top part of the concrete lining and retain earth fill. Cross sections of the walls vary over the entire length. Two sections of the south wall and one section of the north wall were analyzed. The sections and the respective elevations at which stability was checked are as follows: Sta. 15+12.87, north wall, El. 844.0; Sta. 15+12.87, south wall, El. 857.5; Sta. 15+48, south wall, El. 852.0.

TABLE 5

STABILITY ANALYSIS OF INLET CHANNEL WALLS

Section (1)	Loading Case	Location of Resultant: In Middle Third	Location of Resultant: In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure On Rock Kips/S.F.: Heel	Bearing Pressure On Rock Kips/S.F.: Toe
Sta. 14+52	I	yes	-	12.6	17.75	0.70	5.04
south wall	II	no	yes	10.9	14.05	0	5.09
Ht. = 27 ft.	III	yes	-	15.5	17.75	0.05	3.79
Base = 17.75 ft.	IA	no	yes	7.5	8.44	0	12.08
Sta. 14+87.12	I	yes	-	17.0	23.50	0.84	5.88
south wall	II	no	yes	14.7	22.33	0	5.23
Ht. = 27 ft.	III	yes	-	20.8	23.50	0.32	4.28
Base = 23.5 ft.	IA	no	yes	9.3	17.63	0	8.96
Sta. 14+87.12	I	yes	-	34.1	7.00	0.02	2.62
north wall	II	no	yes	30.2	6.35	0	2.68
Ht. = 10 ft.	III	no	yes	35.9	6.51	0	2.36
Base = 7 ft.	IA	no	yes	19.3	3.46	0	5.35

(1) See Plates 8 and 9 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, coefficient of friction of 0.5.

The loading conditions and stability criteria which were applied to the outlet channel walls are identical to those used for the inlet channel walls. Load Cases II and III, however, are not applicable to the outlet channel walls since the water in the channel will never be above El. 842.0 (tailwater concurrent with maximum surcharge elevation of impoundment), which is below the elevations at which stability was checked.

The results of the stability analysis of the outlet channel walls are contained in Table 6. Stability criteria are satisfied for all sections considered.

TABLE 6

STABILITY ANALYSIS OF OUTLET CHANNEL WALLS

Section (1)	Loading Case	Location of Resultant: In Middle Third	Location of Resultant: In Base	Sliding Factor of Safety (2)	Length of Base in Bearing (ft)	Bearing Pressure on Rock Kips/S.F.: Heel	Bearing Pressure on Rock Kips/S.F.: Toe
Sta. 15+12.87	I	yes	-	59.4	5.25	0.20	1.55
north wall	II	Load Case II	not applicable				
Ht. = 6.5 ft.	III	Load Case III	not applicable				
Base = 5.25 ft.	IA	no	yes	32.4	3.71	0	2.48
Sta. 15+12.87	I	yes	-	18.7	16.00	0.31	5.07
south wall	II	Load Case II	not applicable				
Ht. = 21 ft.	III	Load Case III	not applicable				
Base = 16 ft.	IA	no	yes	10.4	9.64	0	8.93
Sta. 15+48	I	yes	-	24.6	8.50	0.49	2.42
south wall	II	Load Case II	not applicable				
Ht. = 13 ft.	III	Load Case III	not applicable				
Base = 8.5 ft.	IA	no	yes	14.6	4.64	0	5.32

(1) See Plates 8, 9 and 10 for details.
(2) Factor of safety calculated for bond shear value of 80 psi, coefficient of friction of 0.5.

PART III

RECOMMENDATIONS

3.1 Overview

The inlet channel walls, outlet channel walls, gate structure and operating house satisfy the current criteria for stability, and no modifications is required. The three spillways do not satisfy criteria, and remedial measures are recommended.

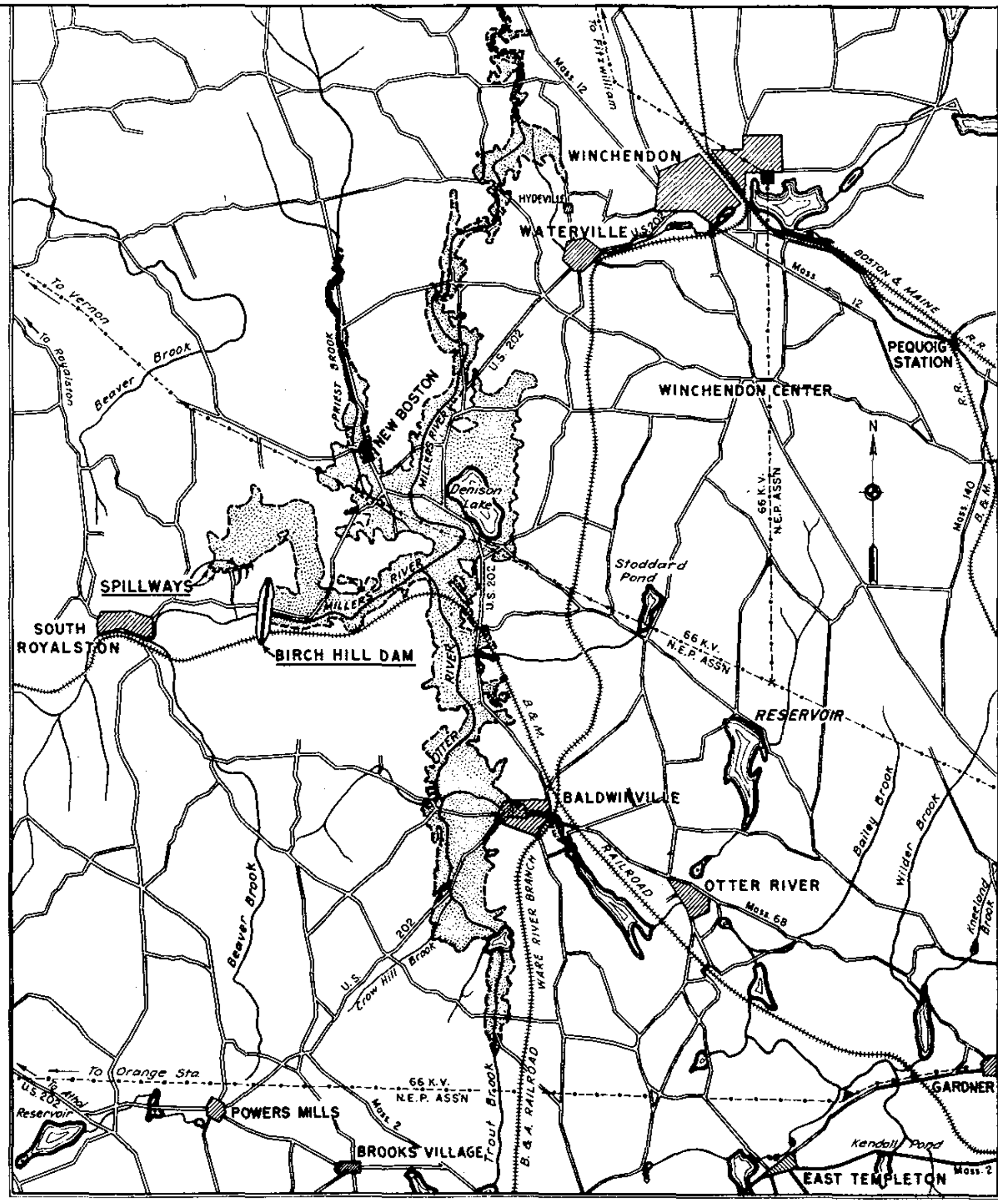
3.2 Remedial Measures for Spillways

Remedial measures are recommended to strengthen the entire length of the main spillway, auxiliary spillway, and third spillway, for a total length of 1190 feet. Vertical rock anchors, 1.0 inch diameter threaded bars with an ultimate strength of 150 kips per square inch, would be installed into 3 inch diameter predrilled holes and extend approximately 20 feet into rock. The bars would be grouted and post-tensioned. Using a design capacity of 76.7 kips per anchor, the spacing of the anchors would be as follows: 6 feet for the main spillway, 9 feet for the auxiliary spillway, and 8.5 feet for the third spillway. It is estimated that 7640 lineal feet of anchors are required. Estimating the present cost to install the anchors at $30 per lineal foot, the total cost to stabilize the three spillways is $230,000.

APPENDIX A

SELECTED RECORD DRAWINGS

DWG. NO.	TITLE	PLATE NO.
CT-1-1343, Sh. No. 1	Project Location and Index	1
CT-1-1345, Sh. No. 10	General Plan	2
CT-1-1348, Sh. No. 13	Spillway - Plan and Profile	3
CT-1-1349, Sh. No. 14	Spillway - Sections	4
CT-1-1350, Sh. No. 15	Outlet Works - Plan	5
CT-1-1352, Sh. No. 17	Gate Structure - Details No. 1	6
CT-1-1353, Sh. No. 18	Gate Structure - Details No. 2	7
CT-1-1360, Sh. No. 25	Outlet Works - Wall Details No. 1	8
CT-1-1561, Sh. No. 26	Outlet Works - Wall Details No. 2	9
CT-1-1560, Sh. No. 26A	Outlet Works - Wall Details No. 3	10
CT-1-1366, Sh. No. 31	Gates and Accessories - General Arrangement	11



VICINITY MAP

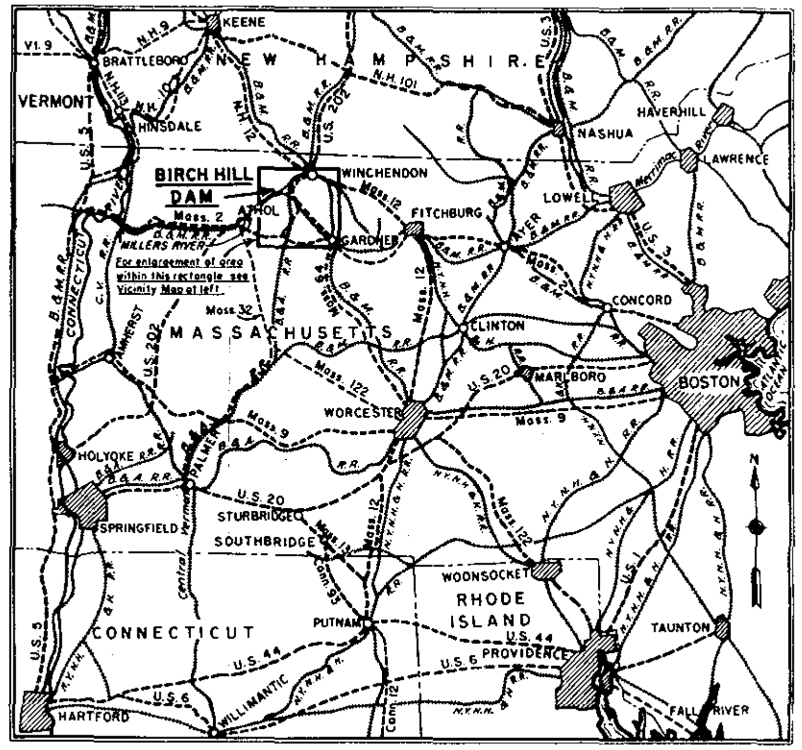
SCALE 1 MILES

LEGEND

- = HIGHWAYS
- = RAILROADS
- = ELECTRIC POWER LINE
- = MAXIMUM RESERVOIR FLOW LINE
- ▲ = ELECTRIC SUBSTATION
- ■ = HYDROELECTRIC GENERATING STATION

INDEX TO DRAWINGS

SHEET NO.	DESCRIPTION	FILE NO.
1	PROJECT LOCATION AND INDEX	CT-1-1343
2	HYDROGRAPHS	CT-3-1097
3	PLAN OF SUBSURFACE EXPLORATION	CT-2-1208
4	RECORD OF SUBSURFACE EXPLORATION LOGS NO.1	CT-2-1209
5	RECORD OF SUBSURFACE EXPLORATION LOGS NO.2	CT-2-1210
6	RECORD OF SUBSURFACE EXPLORATION PROFILE AND SECTIONS NO.1	CT-2-1211
7	RECORD OF SUBSURFACE EXPLORATION PROFILE AND SECTIONS NO.2	CT-2-1212
8	BORROW AREAS AND RECORD OF BORROW EXPLORATIONS	CT-2-1213
9	WORK AREA	CT-1-1344
10	*GENERAL PLAN*	*CT-1-1345*
11	EMBANKMENT DETAILS NO.1	CT-1-1346
12	EMBANKMENT DETAILS NO.2	CT-1-1347
13	SPILLWAY - PLAN AND PROFILE	CT-1-1348
14	SPILLWAY - SECTIONS	CT-1-1349
15	OUTLET WORKS-PLAN	CT-1-1350
16	GATE STRUCTURE-PLAN AND ELEVATIONS	CT-1-1351
17	GATE STRUCTURE-DETAILS NO.1	CT-1-1352
18	GATE STRUCTURE-DETAILS NO.2	CT-1-1353
19	GATE STRUCTURE-DETAILS NO.3	CT-1-1354
20	GATE STRUCTURE STEEL REINFORCEMENT NO.1	CT-1-1355
21	GATE STRUCTURE STEEL REINFORCEMENT NO.2	CT-1-1356
22	GATE STRUCTURE STEEL REINFORCEMENT NO.3	CT-1-1357
23	GATE STRUCTURE STEEL REINFORCEMENT NO.4	CT 1-1358
24	GATE STRUCTURE-STEEL REINFORCEMENT NO.5	CT-1-1359
25	OUTLET WORKS-WALL DETAILS NO.1	CT-1-1360
▲26	OUTLET WORKS-WALL DETAILS NO.2	CT-1-1561
▲26A	OUTLET WORKS-WALL DETAILS NO.3	CT-1-1560
27	WALLS-STEEL REINFORCEMENT NO.1	CT-1-1475
▲28	WALLS-STEEL REINFORCEMENT NO.2	CT-1-1562
29	MISCELLANEOUS METAL DETAILS NO.1	CT-1-1364
30	MISCELLANEOUS METAL DETAILS NO.2	CT-1-1365
31	GATES AND ACCESSORIES GENERAL ARRANGEMENT	CT-1-1366
32	GATES AND ACCESSORIES CLEARANCE FOR 15 TON CRANE	CT-1-1367
33	OPERATING HOUSE-DETAILS NO.1	CT-1-1368
34	OPERATING HOUSE-DETAILS NO.2	CT-1-1369
35	OPERATING HOUSE-DETAILS NO.3	CT-1-1370
36	OPERATING HOUSE-DETAILS NO.4	CT-1-1371
37	OPERATING HOUSE STRUCTURAL STEEL NO.1	CT-1-1372
38	OPERATING HOUSE STRUCTURAL STEEL NO.2	CT-1-1373
39	ACCESS ROAD - PLAN	CT-1-1546
40	*ACCESS ROAD - SECTIONS*	*CT-1-1375*
▲41	ACCESS ROAD - BRIDGE	CT-1-1376
▲42	ACCESS ROAD BRIDGE STEEL REINFORCEMENT NO.1	CT-1-1377
▲43	ACCESS ROAD BRIDGE STEEL REINFORCEMENT NO.2	CT-1-1378
44	REINFORCEMENT SCHEDULE NO.1	CT-1-1379
45	REINFORCEMENT SCHEDULE NO.2	CT-1-1380
46	REINFORCEMENT SCHEDULE NO.3	CT-1-1381
47	REINFORCEMENT SCHEDULE NO.4	CT-1-1382
48	ELECTRIC LIGHT AND POWER NO.1	CT-1-1383
49	ELECTRIC LIGHT AND POWER NO.2	CT-1-1384



LOCATION MAP

SCALE 10 0 10 20 MILES

LEGEND

- = HIGHWAYS
- = RAILROADS

RECORD DRAWINGS

KEY	DATE	REVISION (Indicated by △)	REV. BY	CK. BY	AP. BY
▲	5/14/41	Sheet 26A added, File Nos. changed	WAC		
▲	10/29/40	Sheets No. 41, 42 and 43 deleted			

CONNECTICUT RIVER FLOOD CONTROL

BIRCH HILL DAM

PROJECT LOCATION AND INDEX

MILLERS RIVER — MASSACHUSETTS

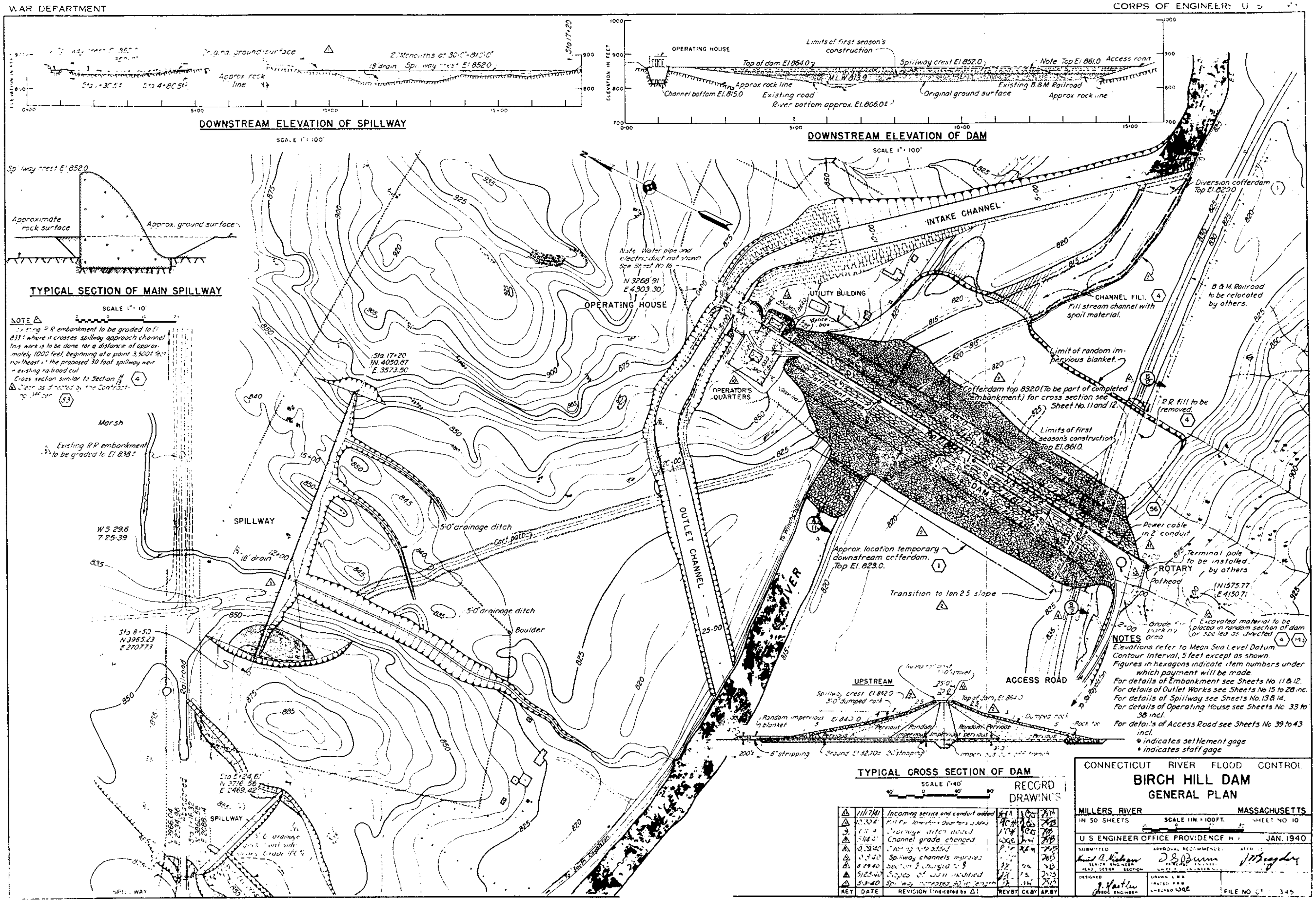
IN 50 SHEETS — SCALES AS SHOWN — SHEET NO. 1

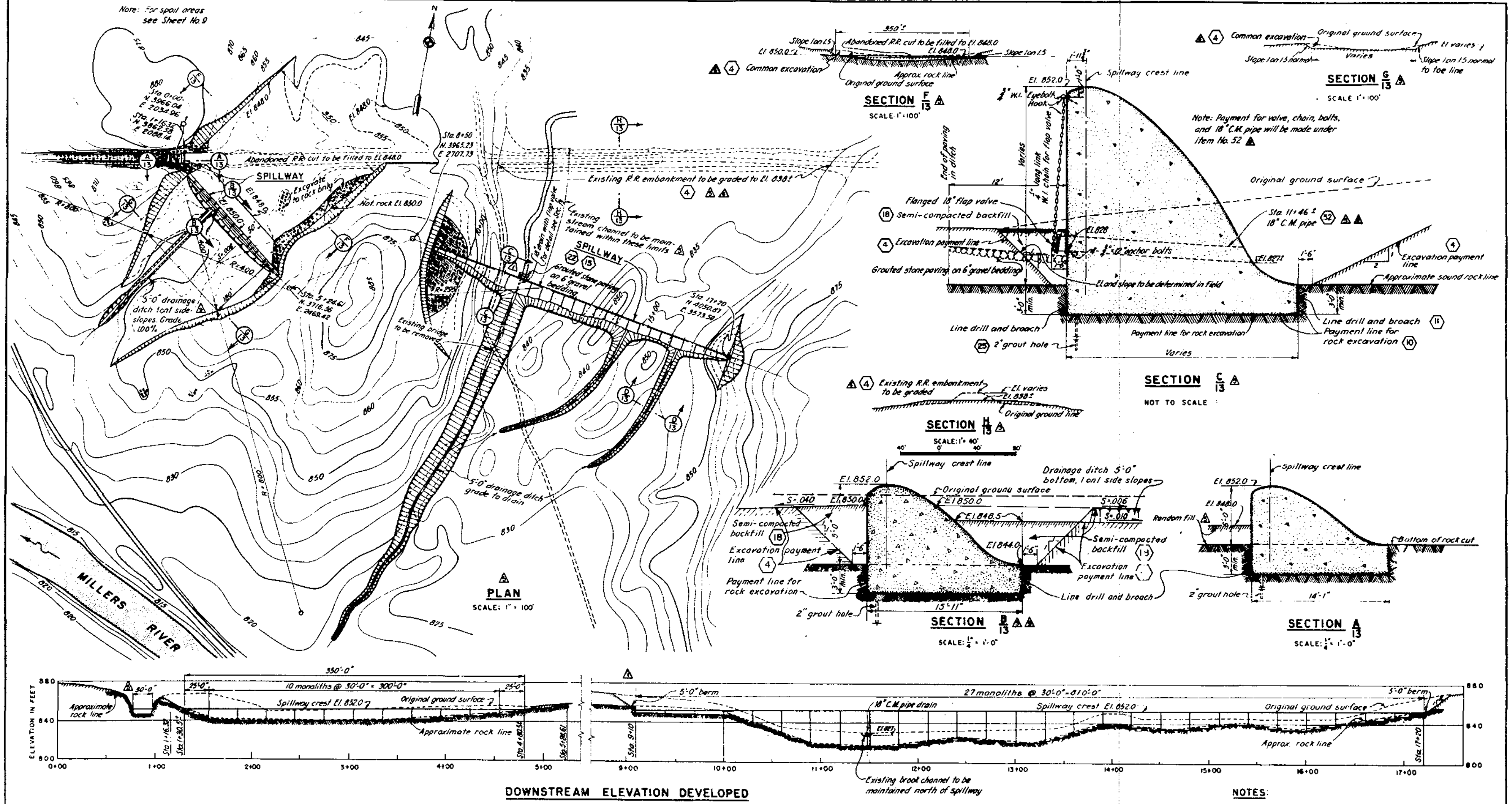
U. S. ENGINEER OFFICE, PROVIDENCE, R. I. — JAN. 1940

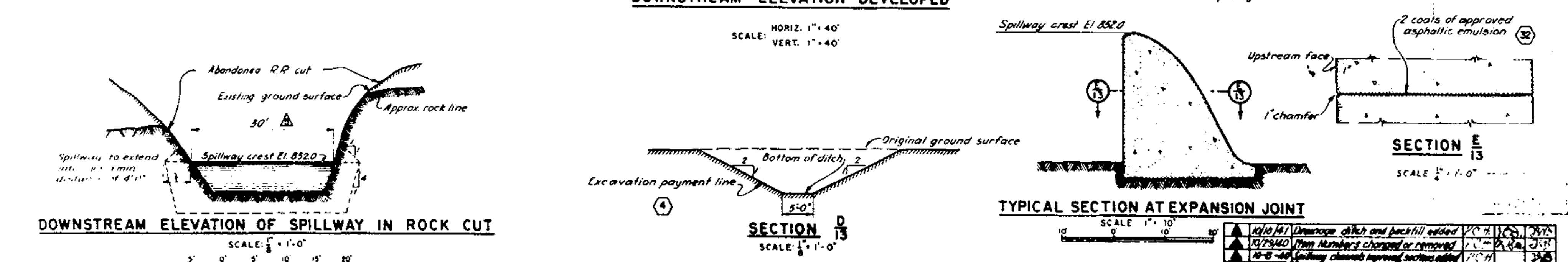
SUBMITTED: SENIOR ENGINEER — APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, F. & S. ENGINEERING DIV. — APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

DESIGNED: ASSOC. ENGINEER — DRAWN: E. A. H. — TRACED: C. J. H. — CHECKED: WAC

FILE NO. CT-1-1343


DOWNSTREAM ELEVATION OF SPILLWAY
SCALE 1"=100'
Original ground surface
Approx. rock line
18"drain Spillway crest El 852.0
DOWNSTREAM ELEVATION OF DAM
SCALE 1"=100'
OPERATING HOUSE
Limits of first season's construction
Top of dam El 864.0
Spillway crest El 852.0
Note Top El 861.0
Access road
Approx rock line
Channel bottom El 815.0
Existing road
River bottom approx. El 806.0±
Original ground surface
Existing B.&M. Railroad
Spillway crest El 852.0
Approximate rock surface
Approx. ground surface
TYPICAL SECTION OF MAIN SPILLWAY
SCALE 1"=10'
Marsh
Existing R.R. embankment to be graded to El 838±
SPILLWAY
5'0" drainage ditch
Cart path
Boulder
Railroad
OPERATING HOUSE
OPERATOR'S QUARTERS
UTILITY BUILDING
INTAKE CHANNEL
OUTLET CHANNEL
Diversion cofferdam Top El 823.0
CHANNEL FILL Fill stream channel with spoil material.
B.&M. Railroad to be relocated by others.
Limit of random impervious blanket.
Cofferdam top 832.0 (To be part of completed embankment.) for cross section see Sheet No. 11 and 12.
Limits of first season's construction Top El 861.0.
R.R. fill to be removed.
Power cable in 2" conduit
ROTARY
Terminal pole to be installed by others
Pothead
Approx. location temporary downstream cofferdam. Top El 823.0.
Transition to 1on 2.5 slope
ACCESS ROAD
NOTES
Elevations refer to Mean Sea Level Datum.
Contour interval, 5 feet except as shown.
Figures in hexagons indicate item numbers under which payment will be made.
For details of Embankment see Sheets No. 11 & 12.
For details of Outlet Works see Sheets No. 15 to 28 inc.
For details of Spillway see Sheets No. 13 & 14.
For details of Operating House see Sheets No. 33 to 38 incl.
For details of Access Road see Sheets No. 39 to 43 incl.
• indicates settlement gage
• indicates staff gage
UPSTREAM
TYPICAL CROSS SECTION OF DAM
SCALE 1"=40'
RECORD DRAWINGS
KEY DATE REVISION (Indicated by Δ) REV BY CK BY AP BY
CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
GENERAL PLAN
MILLERS RIVER MASSACHUSETTS
IN 50 SHEETS SCALE 1 IN = 100 FT. SHEET NO. 10
U.S. ENGINEER OFFICE PROVIDENCE R.I. JAN. 1940





NOTES:

Elevations refer to Mean Sea Level Datum.
See Sheet No. 14 for Spillway details.
All concrete on this sheet to be class "B" concrete and will be paid for under Item No. 32
Figures in hexagons indicate Item No. under which payment will be made

KEY	DATE	REVISION (indicated by △)	REV BY	CK BY	AP BY
▲	10/10/41	Drainage ditch and backfill added			
▲	10/23/40	Item Numbers changed or removed			
▲	10-8-40	Spillway channels improved, sections added			
△	5-8-40	Spillway increased 90' in length			

CONNECTICUT RIVER FLOOD CONTROL

BIRCH HILL DAM
SPILLWAY
PLAN AND PROFILE

MILLERS RIVER — MASSACHUSETTS

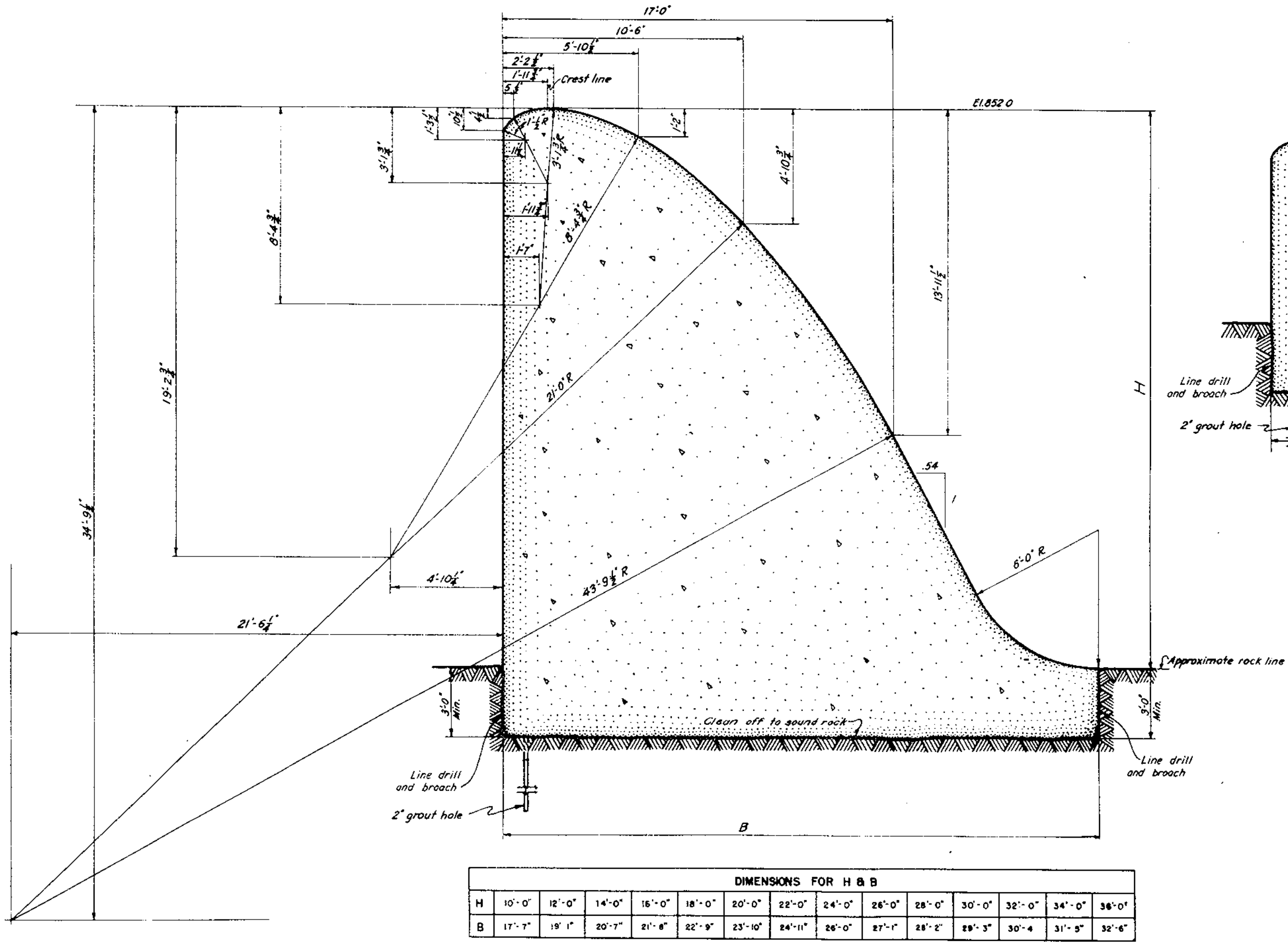
IN 49 SHEETS — SCALE: 1" = 100' — SHEET NO. 13

U. S. ENGINEER OFFICE, PROVIDENCE, R. I. — JAN. 1940

SUBMITTED: DESIGN ENGINEER, HEAD DESIGN SECTION — APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, F. C. ENGINEERING DIV. — APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

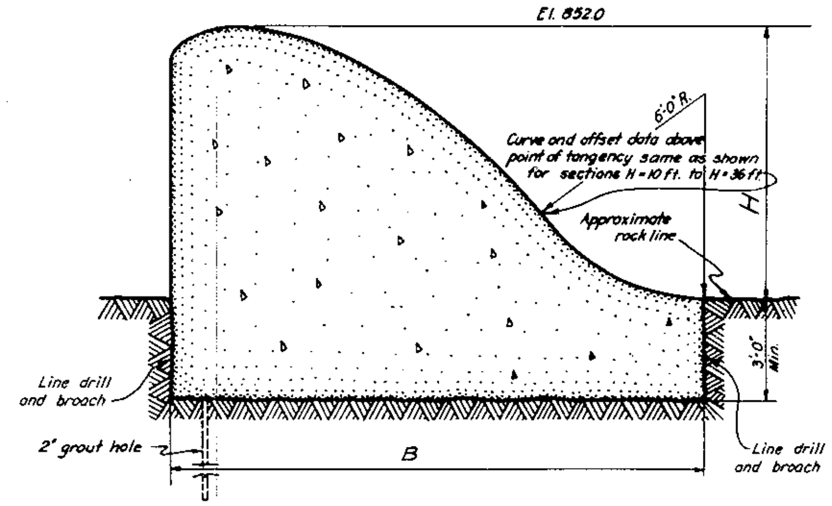
DESIGNED: ASSOC. ENGINEER — DRAWN — TRACED — CHECKED

FILE NO. CT- 348



DIMENSIONS FOR H & B														
H	10'-0"	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"	22'-0"	24'-0"	26'-0"	28'-0"	30'-0"	32'-0"	34'-0"	36'-0"
B	17'-7"	19' 1"	20'-7"	21'-6"	22'-9"	23'-10"	24'-11"	26'-0"	27'-1"	28'-2"	29'-3"	30'-4	31'-5"	32'-6"

SPILLWAY SECTIONS FOR H = 10 FT. TO H = 36 FT.



DIMENSIONS FOR H & B				
H	2'-0"	4'-0"	6'-0"	8'-0"
B	8'-11"	11'-10"	14'-1"	15'-11"

SPILLWAY SECTIONS FOR H = 2 FT. TO H = 8 FT.

NOTES

All concrete shown on this sheet shall be Class "B" and will be paid for under Item No. 32

Location, spacing, depth, and inclination of grout holes shall be determined in field.

For plan and sections of spillway, see Sheet No. 13

Elevations refer to Mean Sea Level Datum.

For reinforcement schedule see Sheet No. 45.

Payment for pressure grouting will be made under Item No. 27

Payment for rock excavation will be made under Item No. 10

RECORD DRAWINGS

KEY	DATE	REVISION (Indicated by △)	REV BY	CK BY	AP BY

CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
SPILLWAY
SECTIONS
MILLERS RIVER MASSACHUSETTS

IN 49 SHEETS SCALE 1 IN = 2 FT SHEET NO 14

U. S. ENGINEER OFFICE, PROVIDENCE, R. I. JAN. 1940

SUBMITTED: Senior Engineer, Head Design Section
APPROVAL RECOMMENDED: Principal Engineer, Chief, F. C. Engineering Div.
APPROVED: Lt. Col. Corps of Engineers, District Engineer

DESIGNED: Assoc. Engineer
DRAWN
TRACED
CHECKED

FILE NO. CT-1349

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

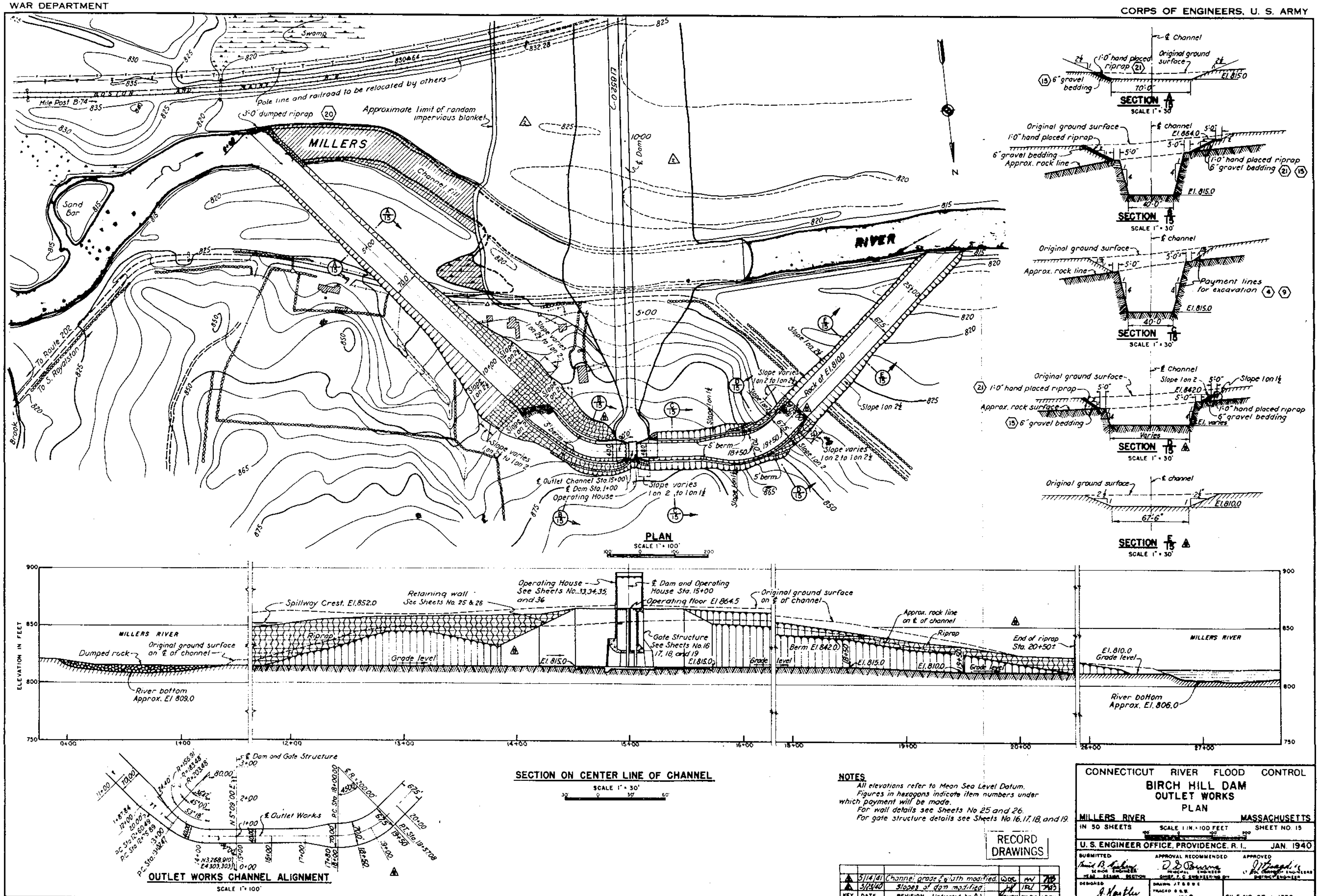
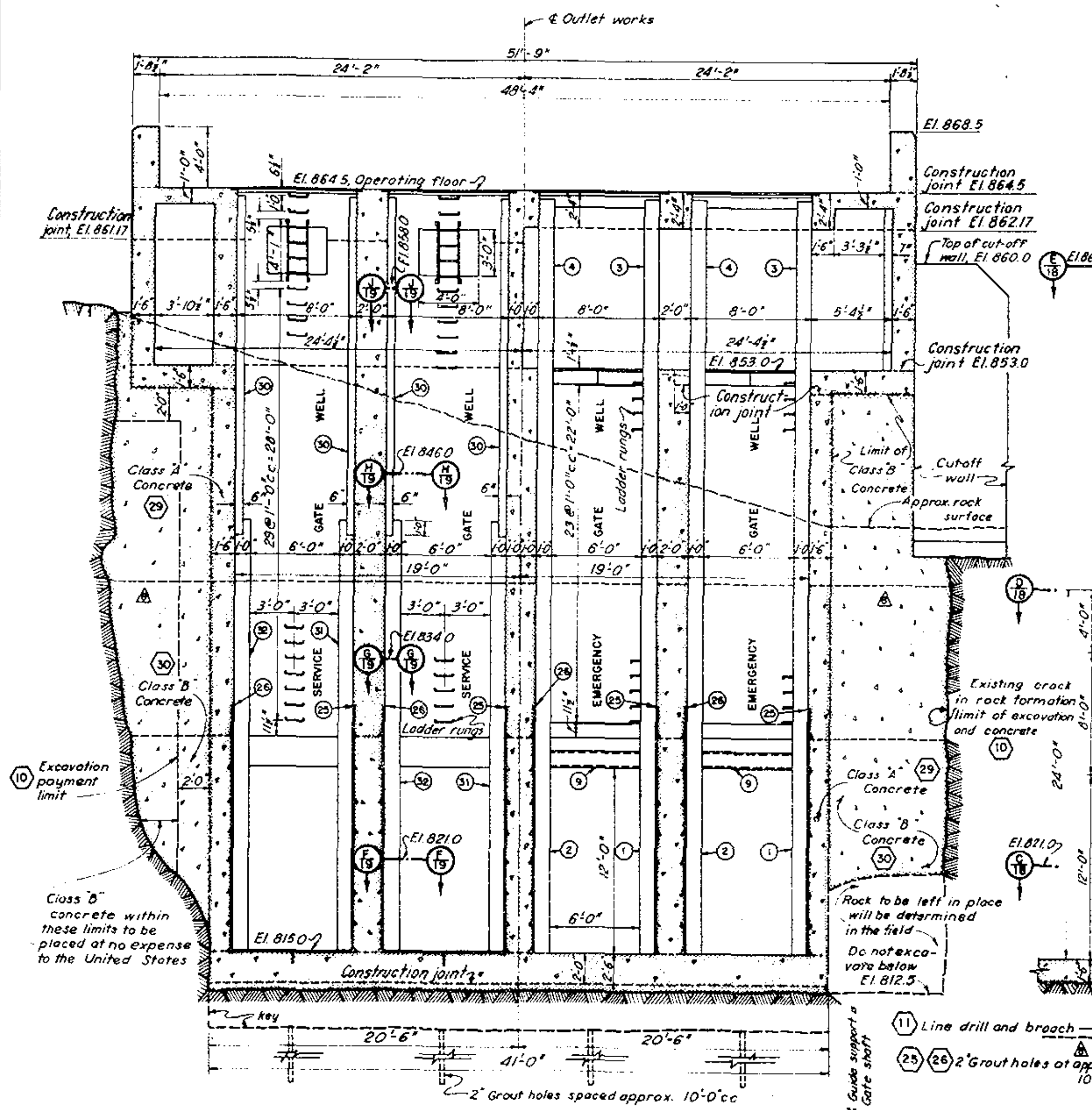
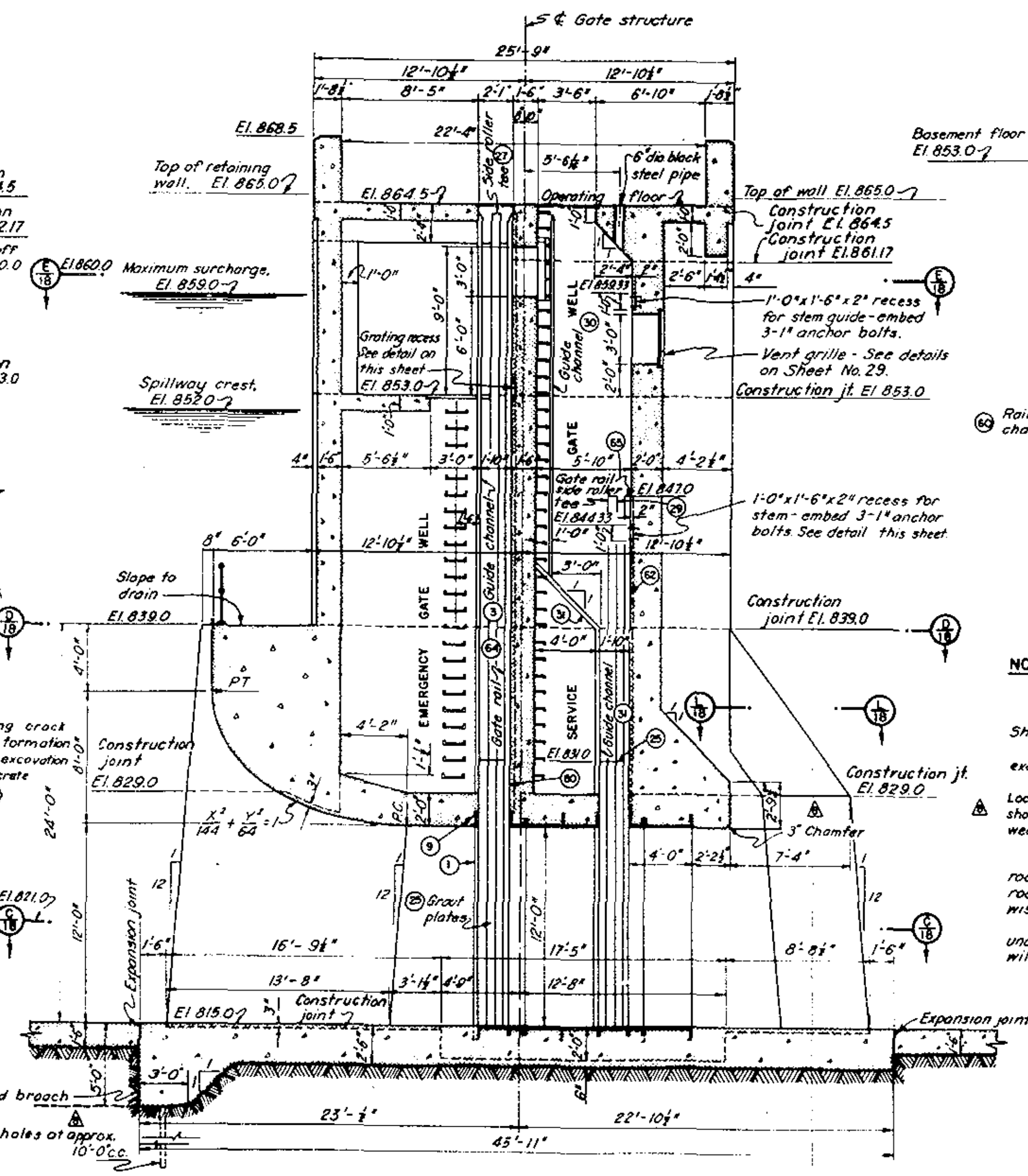


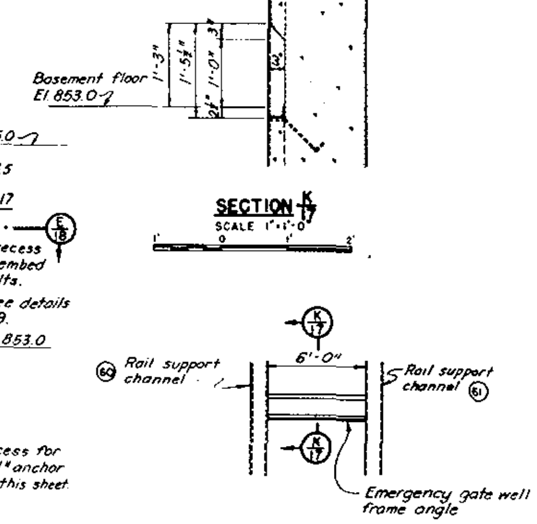
PLATE 5 (15)



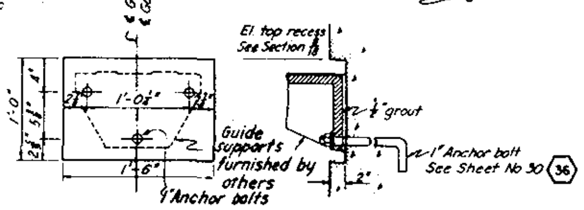
SECTION A/18
SCALE 1/4" = 1'-0"



SECTION B/18
TYPICAL SECTION THRU GATE OPENINGS
SCALE 1/4" = 1'-0"



DETAIL OF GRATING RECESS
SCALE 1/4" = 1'-0"



DETAIL OF GUIDE SUPPORT RECESS
SCALE 1½" = 1'-0"

NOTES

All elevations refer to Mean Sea Level Datum.
For details of expansion joint see Sheet No. 25.
For details of miscellaneous iron and steel see Sheets No. 29 and 30.
All concrete in gate structure shall be Class A except as noted.
Grouting to be done within limits of gate structure in rock. Location, depth, and spacing of grout holes not specifically shown on drawings to be determined in the field by position of weathered and fractured rock zones.
For additional gate structure details see Sheets No. 18 & 19.
Dimensions shown on concrete poured against rock are minimum allowable. Any overbreak of the rock shall be replaced with concrete unless otherwise directed by the contracting officer.
Numbers in circles indicate parts to be furnished under equipment contract. Payment for installation will be made under Item No. 42.

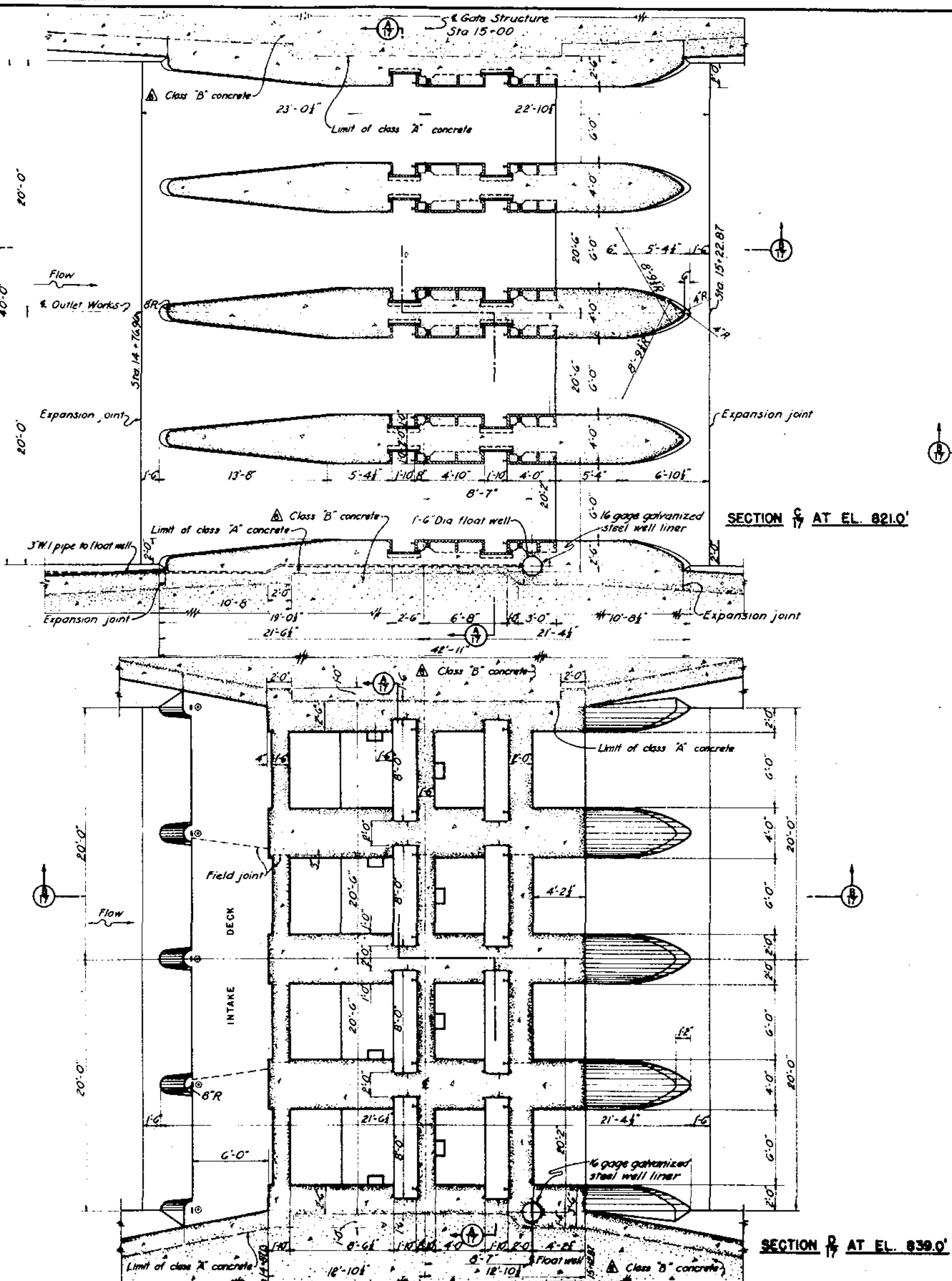
KEY	DATE	REVISION (Indicated by △)	REV BY	CK BY	AP BY
△	3/14/41	Walls and Top of downstream gate opening revised.	WAE		

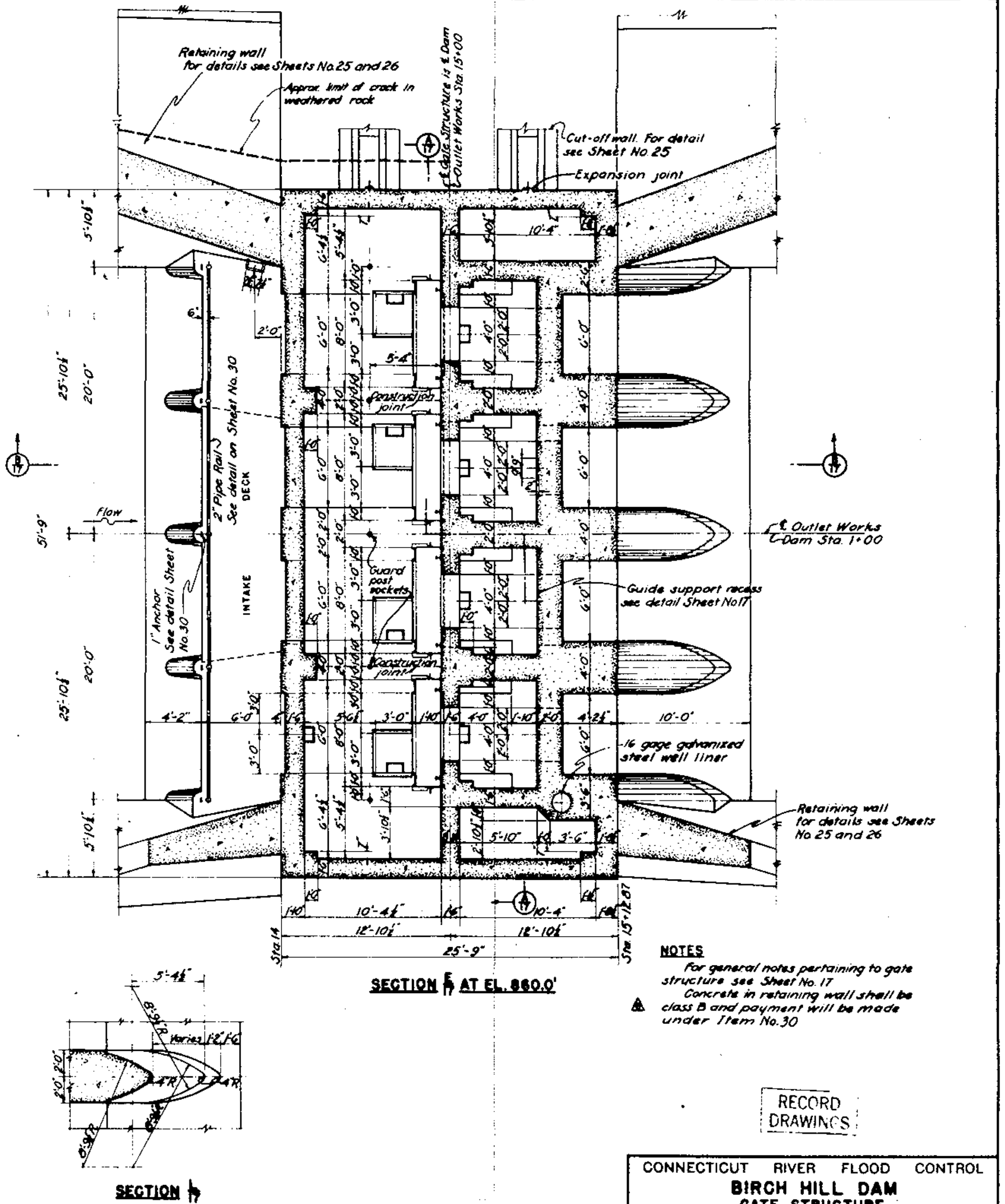
CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
GATE STRUCTURE
DETAILS NO. 1
MILLERS RIVER — MASSACHUSETTS
IN 50 SHEETS — SCALE: 1/4 IN. = 1 FT. — SHEET NO. 17
U. S. ENGINEER OFFICE, PROVIDENCE, R. I. — JAN. 1940
SUBMITTED — APPROVAL RECOMMENDED — APPROVED
DESIGNED — DRAWN — TRACED — CHECKED WAE
FILE NO. CT-1332

RECORD DRAWINGS

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY





NOTES

For general notes pertaining to gate structure see Sheet No. 17

▲ Concrete in retaining wall shall be class B and payment will be made under Item No. 30

RECORD DRAWINGS

KEY	DATE	REVISION (Indicated by △)	REV BY	CK BY	AP BY
▲	5/14/41	Class "B" concrete added			

CONNECTICUT RIVER FLOOD CONTROL

BIRCH HILL DAM

GATE STRUCTURE

DETAILS NO. 2

MILLERS RIVER — MASSACHUSETTS

IN 50 SHEETS — SCALE: 1/4 IN = 1 FT — SHEET NO. 18

U. S. ENGINEER OFFICE, PROVIDENCE, R. I. — JAN. 1940

SUBMITTED — SENIOR ENGINEER, HEAD, DESIGN SECTION; APPROVAL RECOMMENDED — PRINCIPAL ENGINEER, CHIEF, ENGINEERING DIV.; APPROVED — DISTRICT ENGINEER

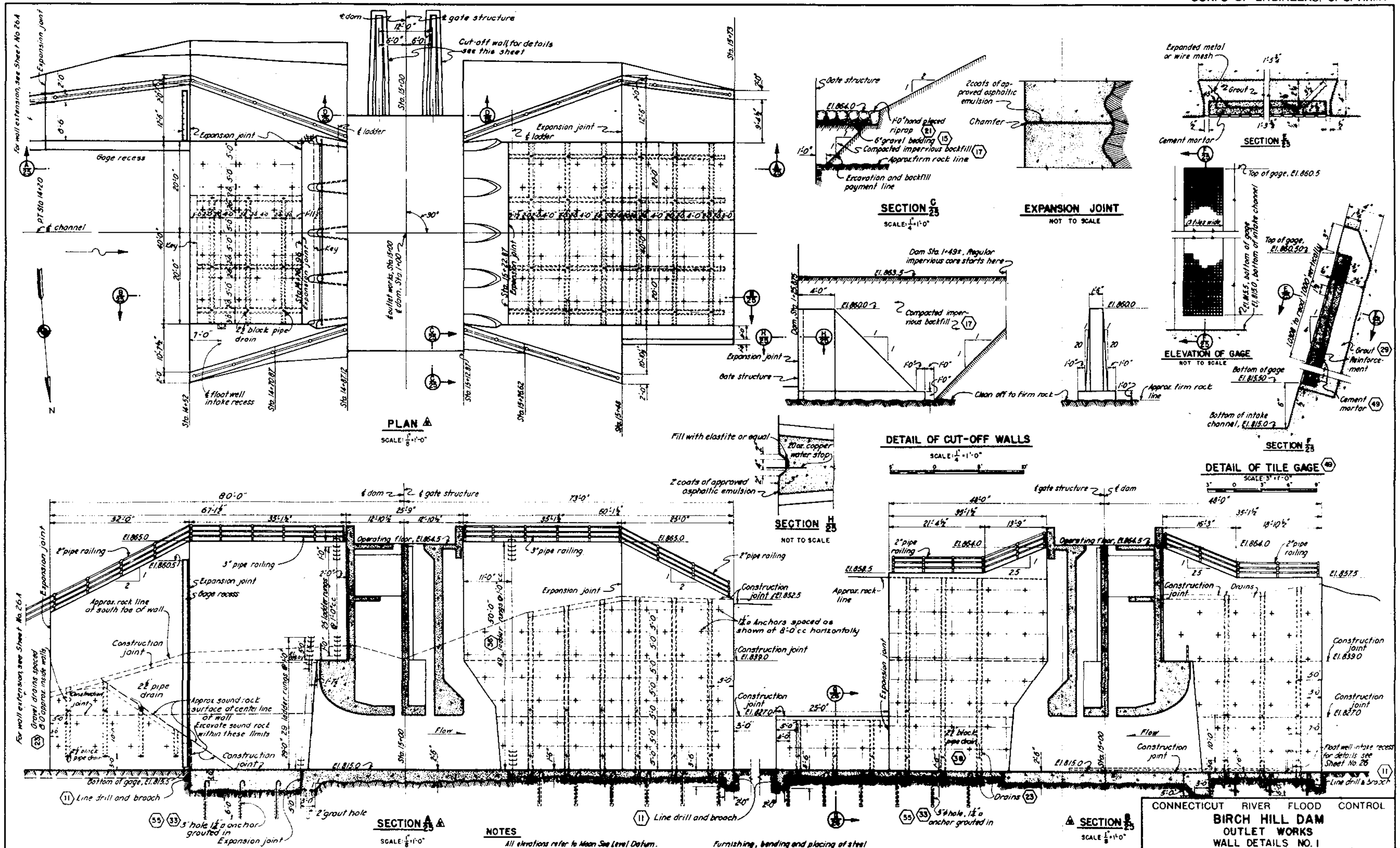
DESIGNED — ASSOC. ENGINEER; DRAWN; TRACED; CHECKED

FILE NO. CT-1-1353

PLATE 7 (18)

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



NOTES

All elevations refer to Mean Sea Level Datum.

Furnishing, bending and placing of anchor bars will be paid for as steel reinforcement under Item No. 33

For details of hand railing and guard fencing see Sheets No. 30 & 12.

Figures in hexagons indicate item number under which payment will be made.

Concrete in reinforced linings shall be Class "A" except as indicated, and payment will be made under Item No. 29.

Concrete in gravity walls to be Class "B".

Furnishing, bending and placing of steel reinforcement will be paid for under Item No. 33

The clear distance shown from outside face of concrete to the rock face shall be a minimum. Any rock overbreak shall be replaced with concrete as shown on Sheets No. 26 and 26 A.

For additional wall details see Sheets No. 26 and 26 A.

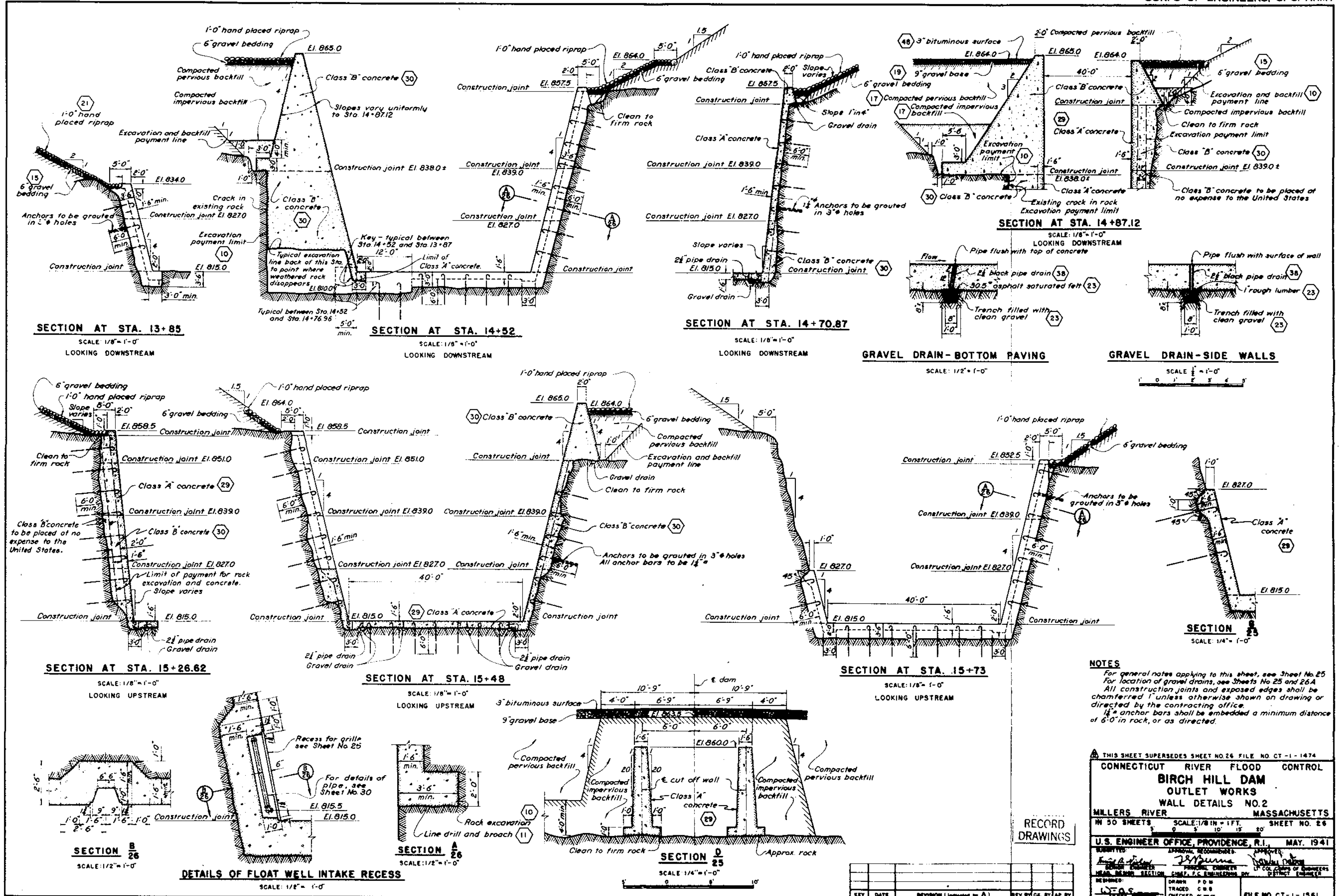
All construction joints and exposed edges shall be chamfered 1" unless otherwise shown on drawings or directed by contracting officer.

RECORD DRAWINGS

KEY	DATE	REVISION (indicated by △)	REV. BY	CK. BY	APBY
△	5/14/41	Upstream south wall revised anchors changed			

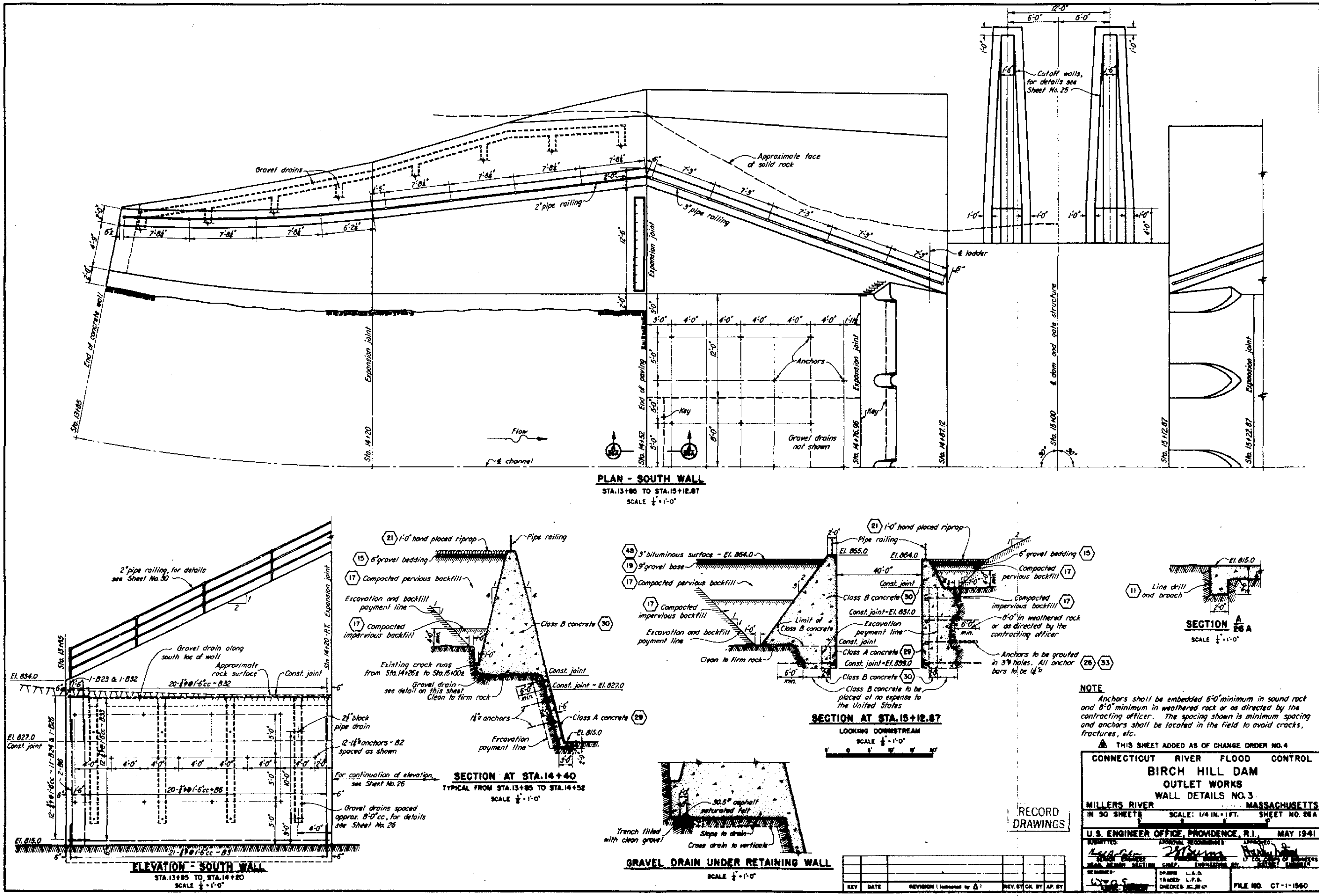
CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
OUTLET WORKS
WALL DETAILS NO. 1
MILLERS RIVER — MASSACHUSETTS
IN 50 SHEETS — SCALE: 1/8 IN. = 1 FT. — SHEET NO. 25
U. S. ENGINEER OFFICE, PROVIDENCE, R. I. — JAN. 1940
SUBMITTED: SENIOR ENGINEER, HEAD, DESIGN SECTION — APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, ENGINEERING — APPROVED: DISTRICT ENGINEER
DESIGNED: ENGINEER — DRAWN D.W.C. — TRACED — CHECKED
FILE NO. C.T.-1-1360

PLATE 8 (25)


SECTION AT STA. 13+85
SCALE: 1/8" = 1'-0"
LOOKING DOWNSTREAM
SECTION AT STA. 14+52
SCALE: 1/8" = 1'-0"
LOOKING DOWNSTREAM
SECTION AT STA. 14+70.87
SCALE: 1/8" = 1'-0"
LOOKING DOWNSTREAM
SECTION AT STA. 14+87.12
SCALE: 1/8" = 1'-0"
LOOKING DOWNSTREAM
GRAVEL DRAIN - BOTTOM PAVING
SCALE: 1/2" = 1'-0"
GRAVEL DRAIN - SIDE WALLS
SECTION AT STA. 15+26.62
SCALE: 1/8" = 1'-0"
LOOKING UPSTREAM
SECTION AT STA. 15+48
SCALE: 1/8" = 1'-0"
LOOKING UPSTREAM
SECTION AT STA. 15+73
SCALE: 1/8" = 1'-0"
LOOKING UPSTREAM
SECTION A/25
SCALE: 1/4" = 1'-0"
SECTION B/26
SCALE: 1/2" = 1'-0"
DETAILS OF FLOAT WELL INTAKE RECESS
SCALE: 1/8" = 1'-0"
SECTION A/26
SCALE: 1/2" = 1'-0"
SECTION D/25
SCALE: 1/4" = 1'-0"
1'-0" hand placed riprap
6" gravel bedding
Compacted pervious backfill
Compacted impervious backfill
Class "B" concrete
Class "A" concrete
Construction joint
Excavation and backfill payment line
Clean to firm rock
Anchors to be grouted in 3" ⌀ holes
Gravel drain
2½" pipe drain
3" bituminous surface
9" gravel base
Recess for grille see Sheet No. 25
For details of pipe, see Sheet No. 30
Rock excavation
Line drill and broach
NOTES
For general notes applying to this sheet, see Sheet No. 25
For location of gravel drains, see Sheets No. 25 and 26A
All construction joints and exposed edges shall be chamfered 1" unless otherwise shown on drawing or directed by the contracting office.
1¼" ⌀ anchor bars shall be embedded a minimum distance of 6'-0" in rock, or as directed.
THIS SHEET SUPERSEDES SHEET NO. 26 FILE NO. CT-1-1474
CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
OUTLET WORKS
WALL DETAILS NO. 2
MILLERS RIVER MASSACHUSETTS
IN 50 SHEETS SCALE: 1/8 IN = 1 FT. SHEET NO. 26
U.S. ENGINEER OFFICE, PROVIDENCE, R.I., MAY 1941
FILE NO. CT-1-1561
RECORD DRAWINGS

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



NOTE

Anchors shall be embedded 6'-0" minimum in sound rock and 8'-0" minimum in weathered rock or as directed by the contracting officer. The spacing shown is minimum spacing and anchors shall be located in the field to avoid cracks, fractures, etc.

THIS SHEET ADDED AS OF CHANGE ORDER NO. 4

CONNECTICUT RIVER FLOOD CONTROL

BIRCH HILL DAM

OUTLET WORKS

WALL DETAILS NO. 3

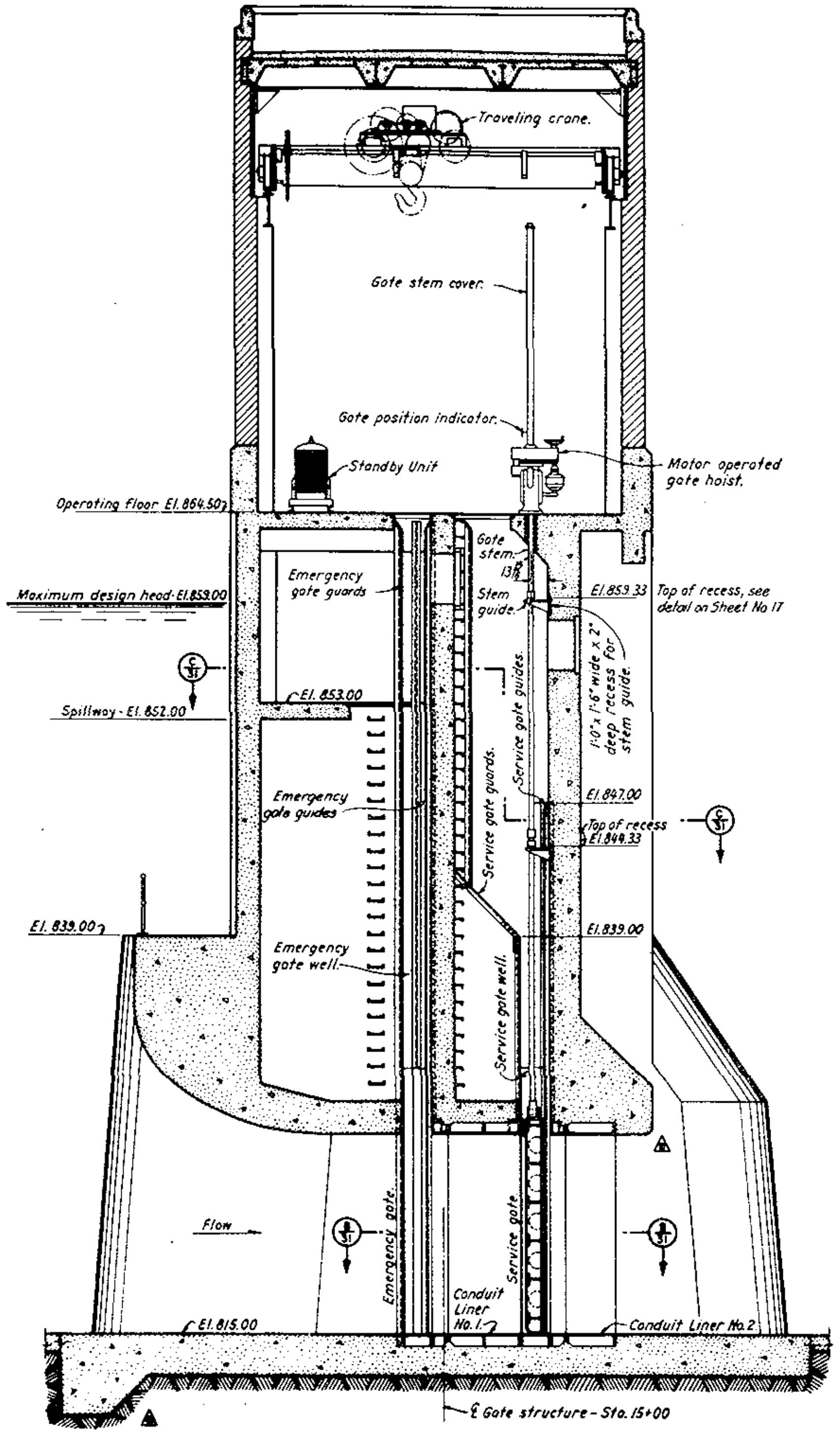
MILLERS RIVER — MASSACHUSETTS

IN 50 SHEETS — SCALE: 1/4 IN. = 1 FT. — SHEET NO. 26A

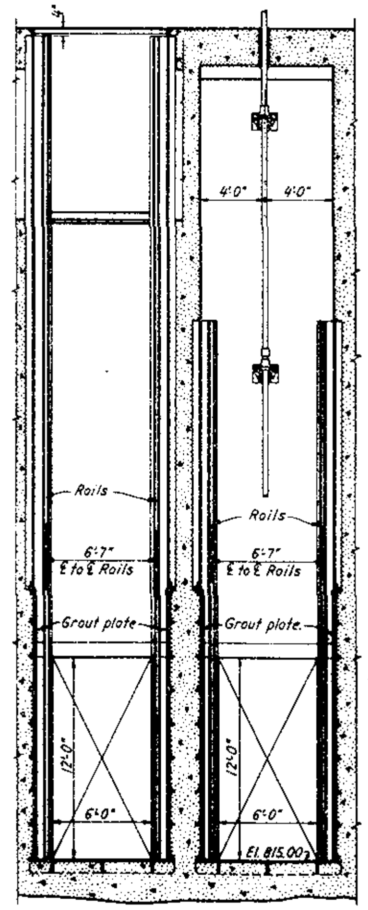
U.S. ENGINEER OFFICE, PROVIDENCE, R.I. — MAY 1941

FILE NO. CT-1-1560

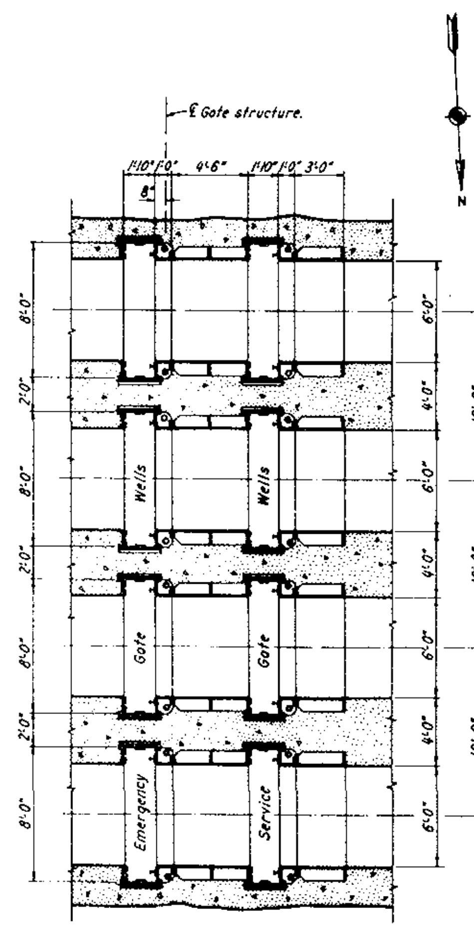
PLATE 10 (26A)



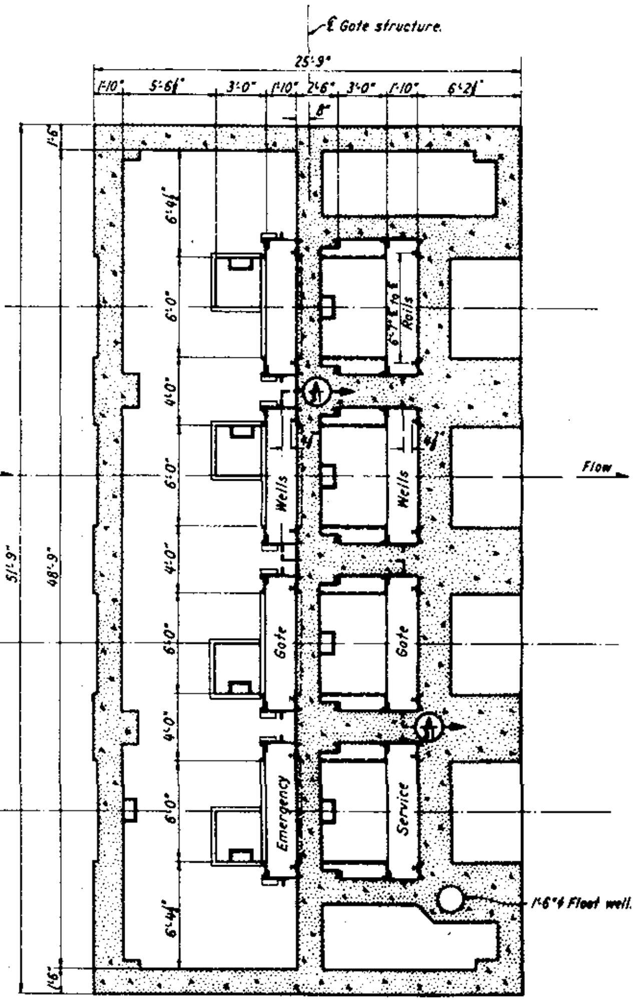
INSTALLATION OF GATES



SECTION A/31
WITH GATES REMOVED



SECTION B/31
WITH GATES REMOVED



SECTION C/31
WITH FLOOR PLATES REMOVED

NOTES

Payment for installing gates, hoists and accessories will be under Item No. 42.
Payment for installing conduit liners will be under Item No. 43.
Payment for furnishing and installing crane will be under Item No. 44.
Payment for furnishing and installing gasoline-electric standby unit will be under Item No. 45.

KEY	DATE	REVISION (indicated by △)			
▲	5-14-41	Shape of conduit exit changed			

RECORD DRAWINGS

CONNECTICUT RIVER FLOOD CONTROL
BIRCH HILL DAM
GATES AND ACCESSORIES
GENERAL ARRANGEMENT
MILLERS RIVER MASSACHUSETTS
IN 50 SHEETS SCALE: 1/4 IN. = 1 FT. SHEET NO. 31
U. S. ENGINEER OFFICE, PROVIDENCE, R. I. JAN. 1940
FILE NO. CT-1-1366